

Memorandum

Date: August 22, 2003

To: Mark Holderman, Chief
Temporary Barriers and Lower San Joaquin

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Jim Wilde, Engineer, WR;
Delta Modeling Section

From: Department of Water Resources

Subject: Modeling Simulation of 2002 South Delta Hydrodynamics

This report describes the details of a hydrodynamic simulation for 2002 as requested the Temporary Barriers and Lower San Joaquin Section in DWR's Bay-Delta Office. The period of simulation extends from January 1, 2002 to December 31, 2002.

To simulate the hydrodynamics, the Delta Modeling Section used DSM2-Hydro. DSM2-Hydro is a one-dimensional open channel unsteady flow model. It is based on a four-point finite difference solution of equations of momentum and continuity. The solution scheme has proven to be stable. The model network is extended north to Sacramento River at I street, and South to San Joaquin River at Vernalis. The downstream boundary is located at Martinez. A 15-minute time history of stage input at Martinez governs how the tide signal penetrates into the Delta.

Boundary conditions

Flow and stage information required at model boundaries were downloaded from the IEP web site (www.iep.water.ca.gov). The IEP database includes data collected by various agencies including DWR and USGS. For some data items, duplicate data from more than one agency was available. DSM2 allows input from multiple sources; however, they have to be assigned a priority order. As the first option DSM2 uses data ranked at the highest priority, and then proceeds to those of lower priority if necessary. Priority was assigned based on data availability, quality of the data, and past experience. Input data, when visually examined using plotting routines, showed some data missing at certain times. These data were identified. In most cases, alternate sources of data filled the gap. The resulting boundary conditions for 2002 are shown in the figures below.

Consumptive use

The Delta Island Consumptive Use (DICU) model provides an estimate of the amount of water diverted from and returned to Delta channels due to agriculture activities. Input to DICU model includes precipitation data, pan evaporation data and

water year types. DICU hydrology data was extended to include precipitation data for 2002. ET adjustments (evapotranspiration data) were made for 2002 using monthly pan evaporation data.

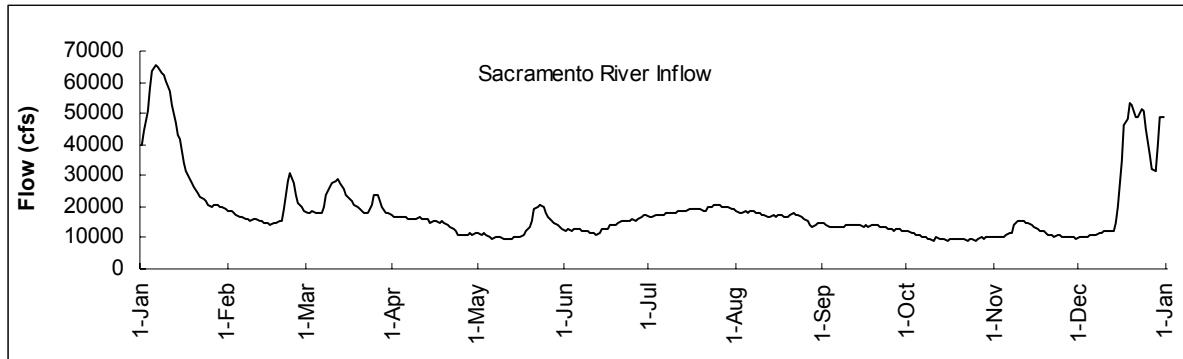


Figure 1. Daily average historical inflow from the Sacramento River, 2002.

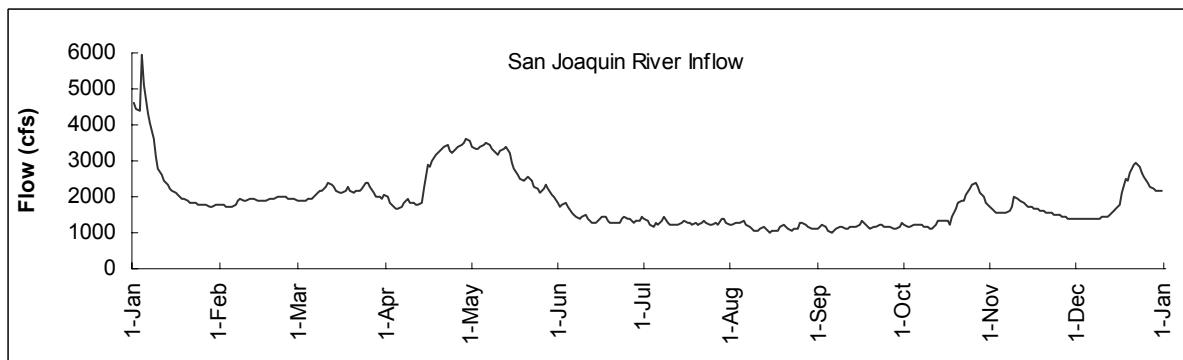


Figure 2. Daily average historical inflow from the San Joaquin River, 2002.

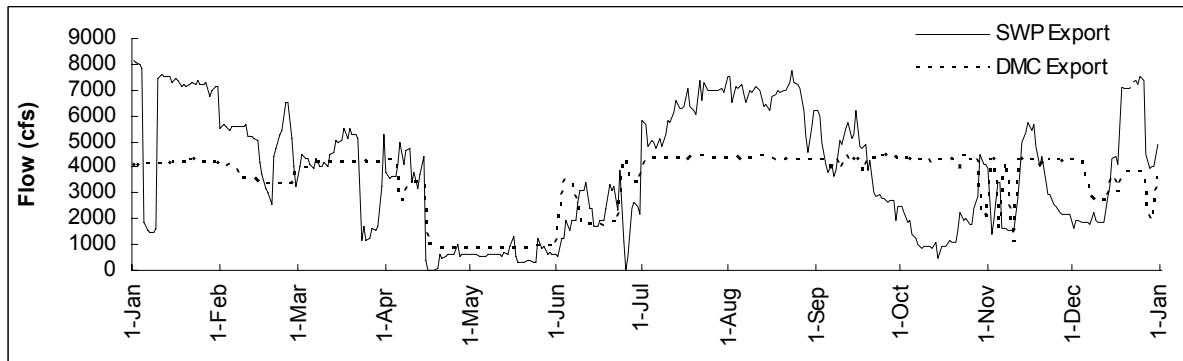


Figure 3. Daily average historical pumping at Banks and Delta Pumping plants, 2002.

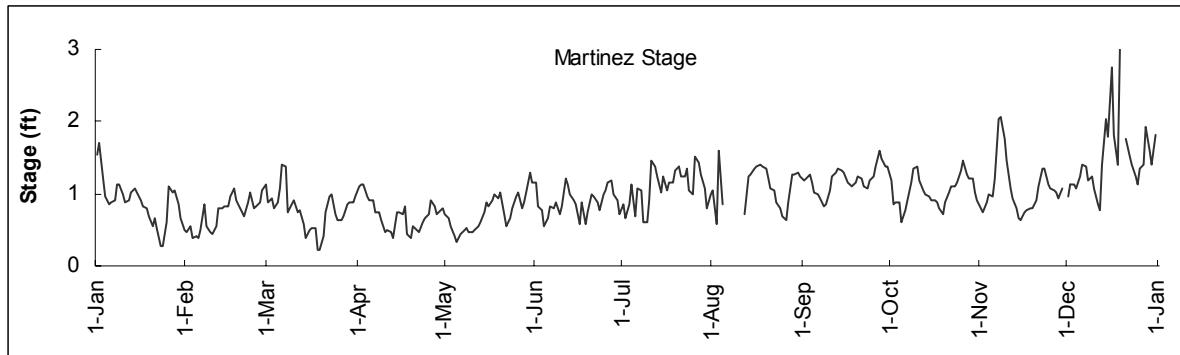


Figure 4. Daily average historical stage at Martinez, 2002.

Delta Structures

All three temporary agricultural barriers were installed in 2002 in addition to the spring and fall barriers at the head of Old River. The fall barrier at the head of Old River varied from the spring barrier by being notched at 0.0 mean sea level. While installation and removal of the temporary barriers may have taken days or weeks, the DSM2 simulation timed the actual installation and removal to effective dates, as inferred from observed water levels. The table below describes the historical and DSM2-assumed operation of all the South Delta Barriers.

Barrier	Installation			Removal		
	Started	Ended	DSM2	Started	Ended	DSM2
Middle River	4/10/02	4/15/02	4/15/02	11/20/02	11/23/02	11/22/02
Old River near DMC	4/1/02	4/18/02	4/15/02	11/16/02	11/29/02	11/28/02
Grant Line Canal	4/1/02	6/12/02	6/7/02	11/14/02	11/25/02	11/24/02
Old River @ Head (spring)	4/2/02	4/18/02	4/15/02	5/22/02	6/7/02	5/25/02
Old River @ Head (fall)	9/24/02	10/4/02	10/4/02	11/11/02	11/21/02	11/21/02

Table 1. Historical and DSM2-assumed south Delta barriers installation and removal, 2002.

For a special study to examine the effect of fish movement associated with tidally operating the Delta Cross Channel, the Delta Cross Channel was alternately opened for approximately 9 hours and then closed for approximately 15 hours in June of 2002. Otherwise, the Delta Cross Channel gates were operated in a typical manner (see table below).

Time Interval					Time Interval						
Date	Time	Date	Time	Status	Date	Time	Date	Time	Status		
1/1/02	0000	-	5/24/02	0924	closed	6/11/02	0029	-	6/11/02	2225	open
5/24/02	0924	-	5/28/02	0924	open	6/11/02	2225	-	6/12/02	0627	closed
5/28/02	0924	-	5/31/02	0925	closed	6/12/02	0627	-	6/12/02	2225	open
5/31/02	0925	-	6/3/02	1917	open	6/12/02	2225	-	6/13/02	0628	closed
6/3/02	1917	-	6/4/02	0429	closed	6/13/02	0628	-	6/13/02	2225	open
6/4/02	0429	-	6/4/02	1926	open	6/13/02	2225	-	6/14/02	0624	closed
6/4/02	1926	-	6/5/02	0426	closed	6/14/02	0624	-	10/16/02	0735	open
6/5/02	0426	-	6/5/02	1924	open	10/16/02	0735	-	10/19/02	0725	closed
6/5/02	1924	-	6/6/02	0425	closed	10/19/02	0725	-	10/19/02	0730	open
6/6/02	0425	-	6/6/02	1927	open	10/19/02	0730	-	11/12/02	0800	half open
6/6/02	1927	-	6/7/02	0428	closed	11/12/02	0800	-	11/12/02	1500	closed
6/7/02	0428	-	6/9/02	2224	open	11/12/02	1500	-	12/3/02	0800	open
6/9/02	2224	-	6/10/02	0627	closed	12/3/02	0800	-	12/10/02	1300	closed
6/10/02	0627	-	6/10/02	2225	open	12/10/02	1300	-	12/16/02	1100	open
6/10/02	2225	-	6/11/02	0029	closed	12/16/02	1100	-	12/31/03	2400	closed

Table 2. Historical Delta Cross Channel operation for 2002.

Accuracy of DSM2 Simulation of 2002 Delta Hydrodynamics

DSM2-simulated stages and flows have been compared to historical data in the south Delta (Figure 5). At the time of this report, flow data was generally only available through June of 2002. Figure 6 shows the historical and DSM2-simulated daily maximum and minimum stages at 11 locations in the south Delta barriers and the daily average stage within Clifton Court Forebay. With the exception of Middle River at Howard Road (MHR) in November, DSM2-simulated stages followed historical stage patterns. Records show the Middle River barrier being removed in mid-November along with the other barriers, yet recorded stages at MHR remained high. The historical values at MHR are from DWR's California Data Exchange Center (CDEC) and have not yet been screened. Other gages nearby did show the expected decrease in stage in late November, making the CDEC values at MHR during this period somewhat suspect.

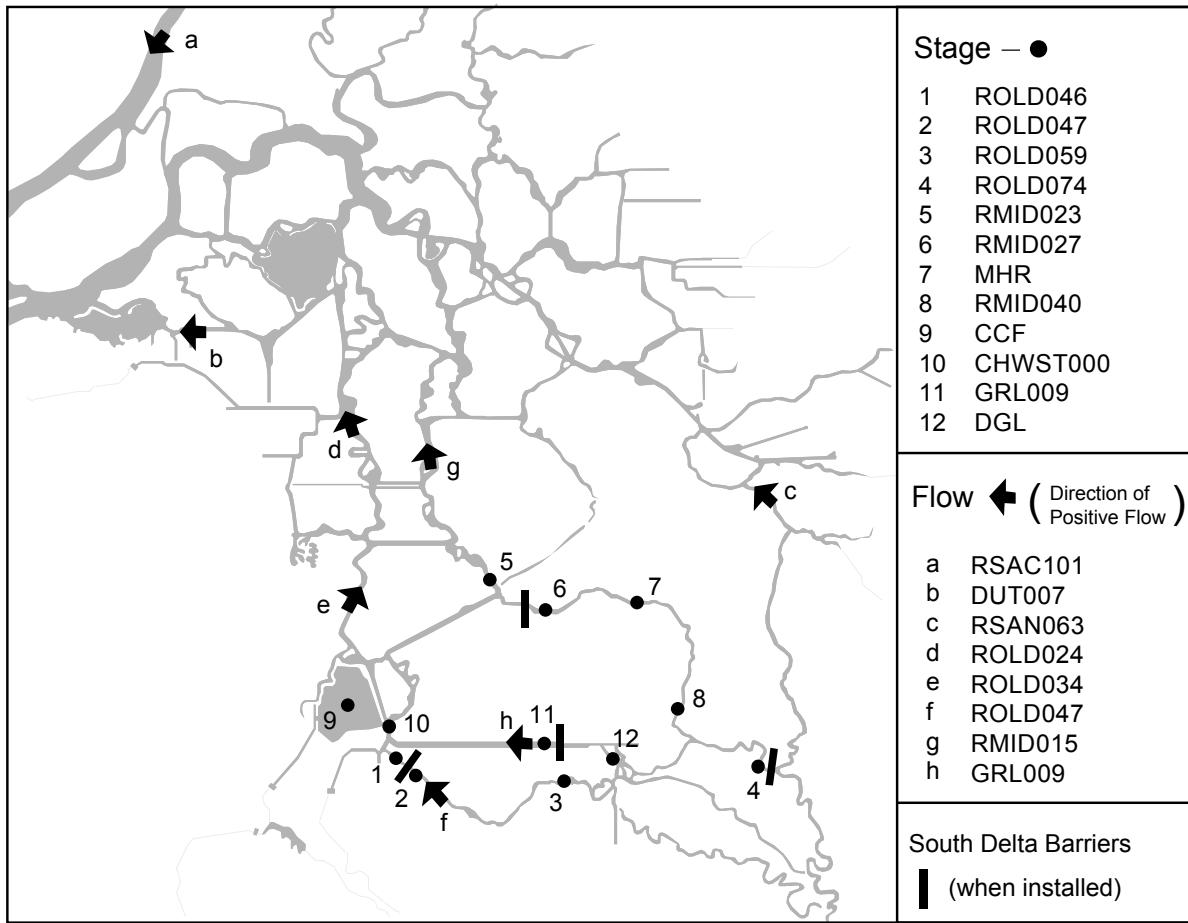


Figure 5. Locations where 2002 historical and DSM2-simulated hydrodynamics compared.

Figure 7 shows the historical and DSM2-simulated daily average flows at 8 locations in the Delta. Flows generated by DSM2 compare well to the available historical flows. However, no comparison is yet possible at a location under the influence of a barrier operation. By common sign convention, positive flows refer to downstream flow while negative flow corresponds to upstream flow (see Figure 5).

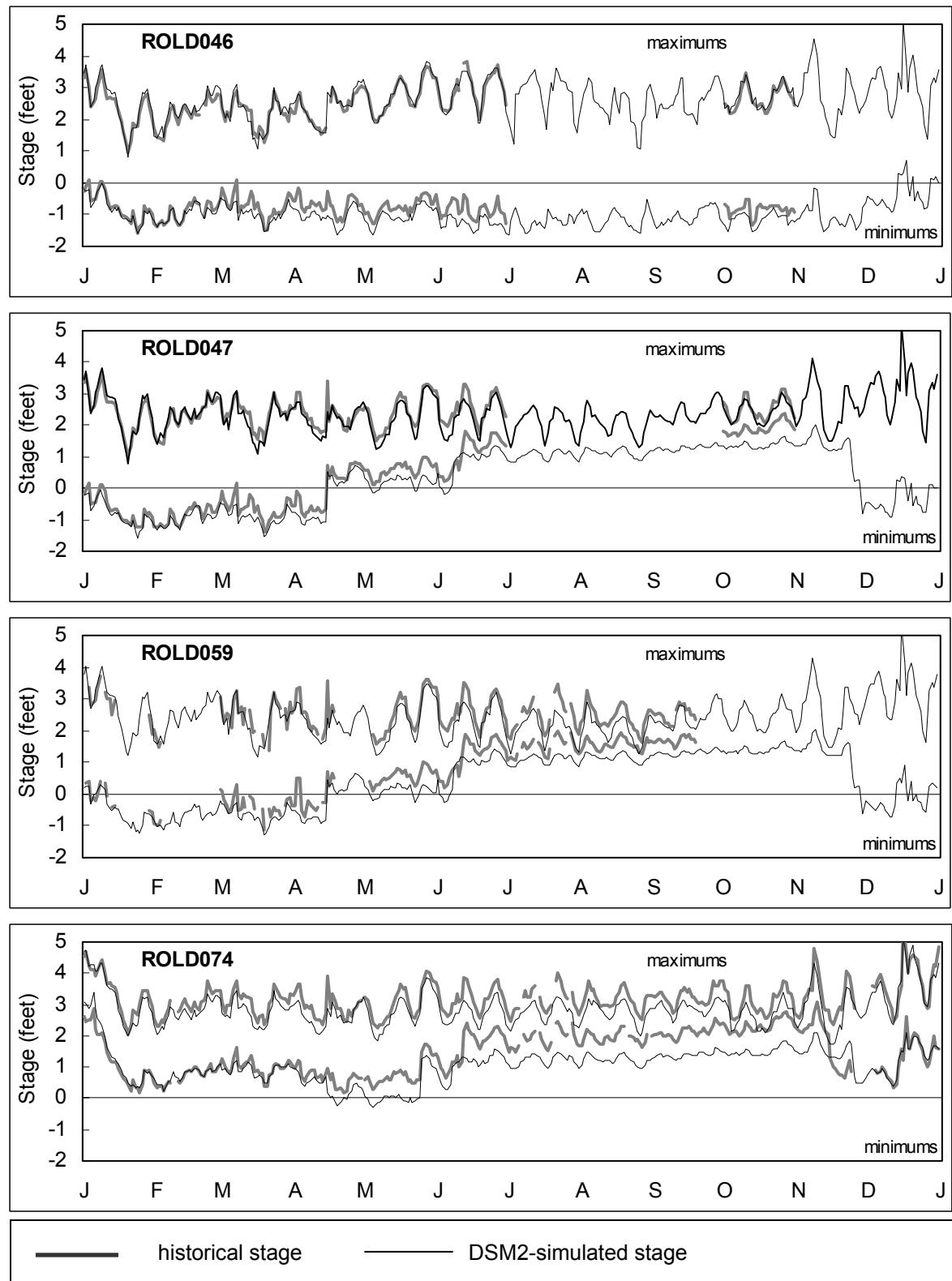


Figure 6. Daily maximum and minimum historical and DSM2-simulated stage, 2002.

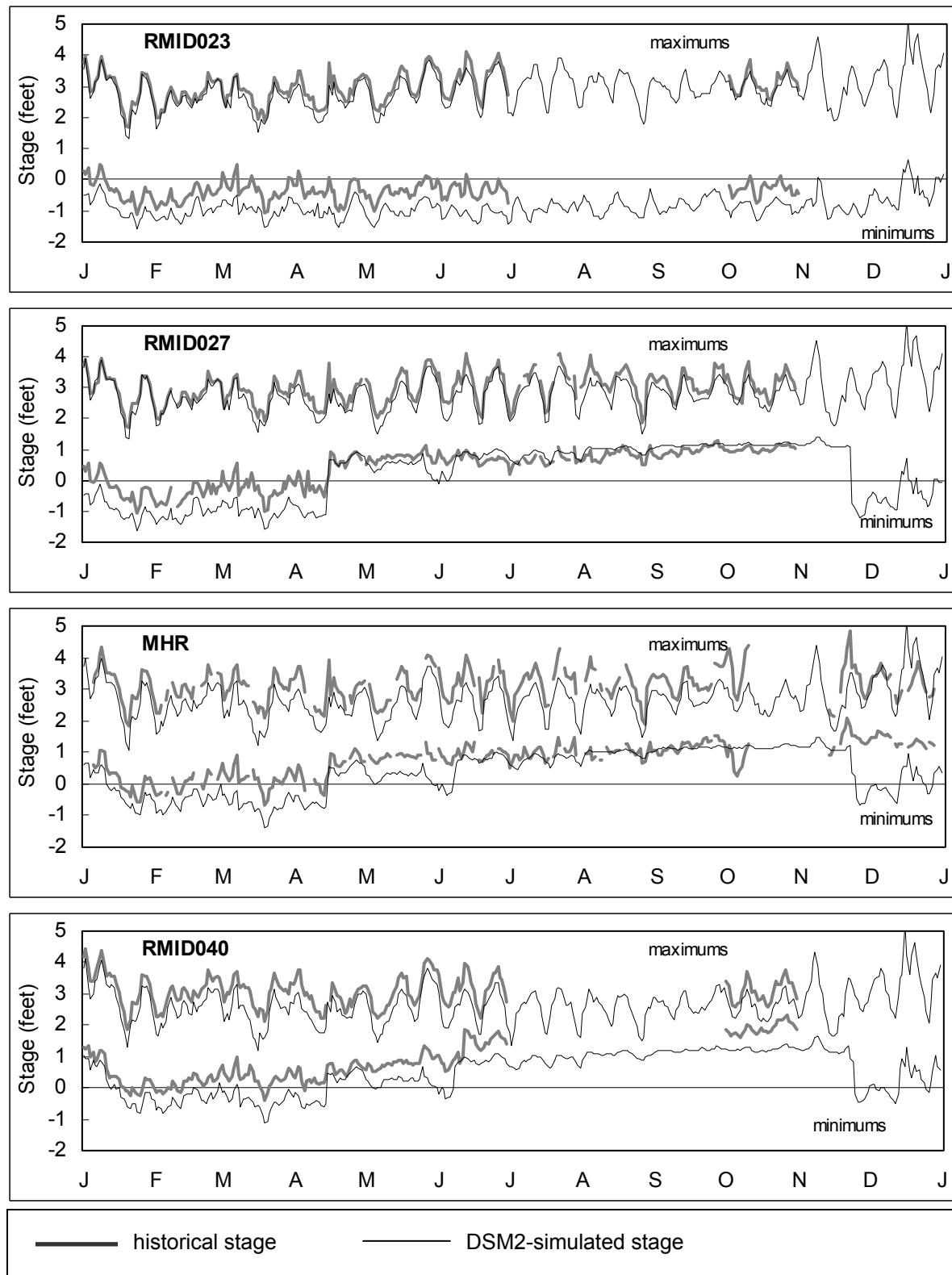


Figure 6-cont. Daily maximum and minimum historical and DSM2-simulated stage, 2002.

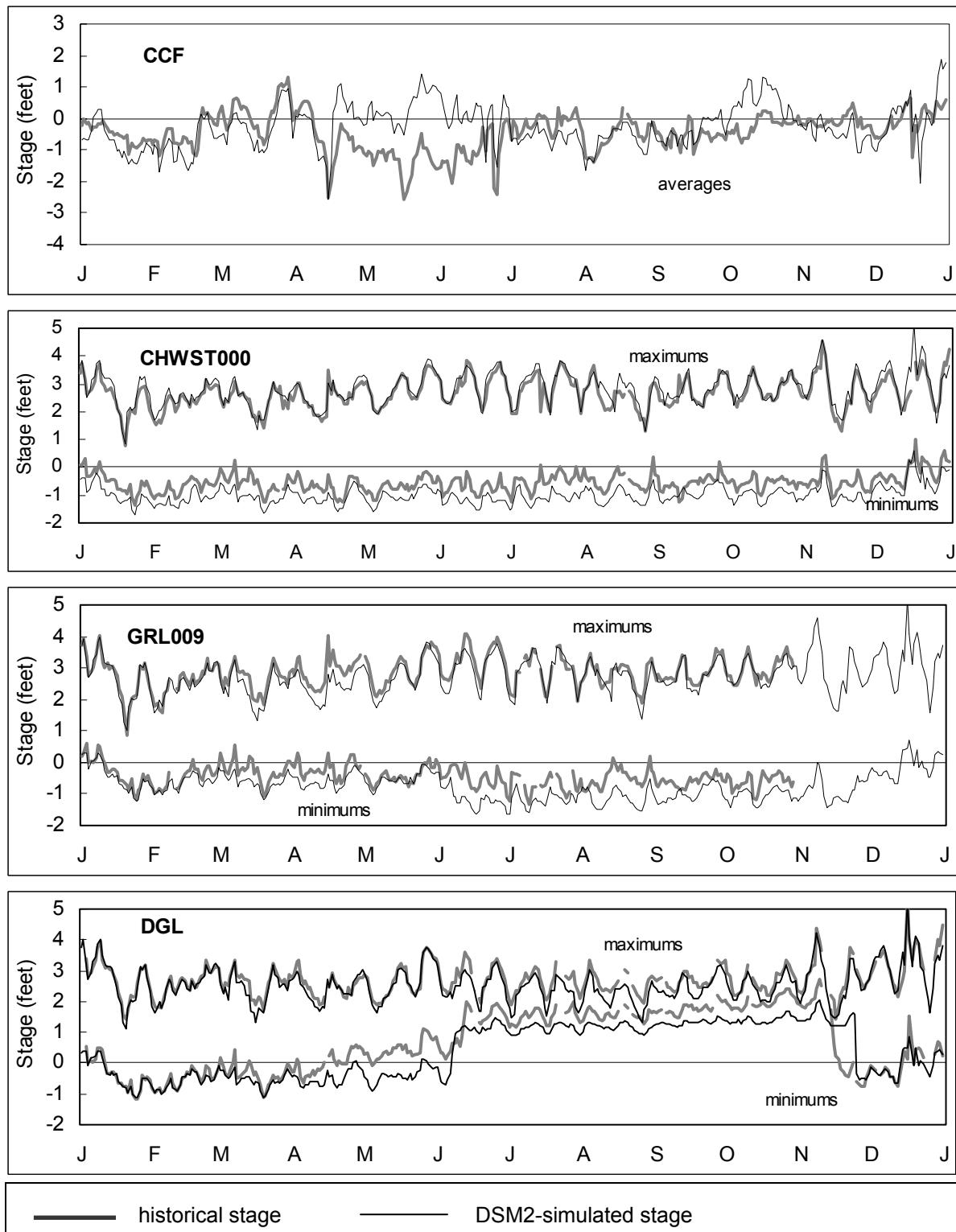


Figure 6-cont. Daily maximum and minimum historical and DSM2-simulated stage, 2002.

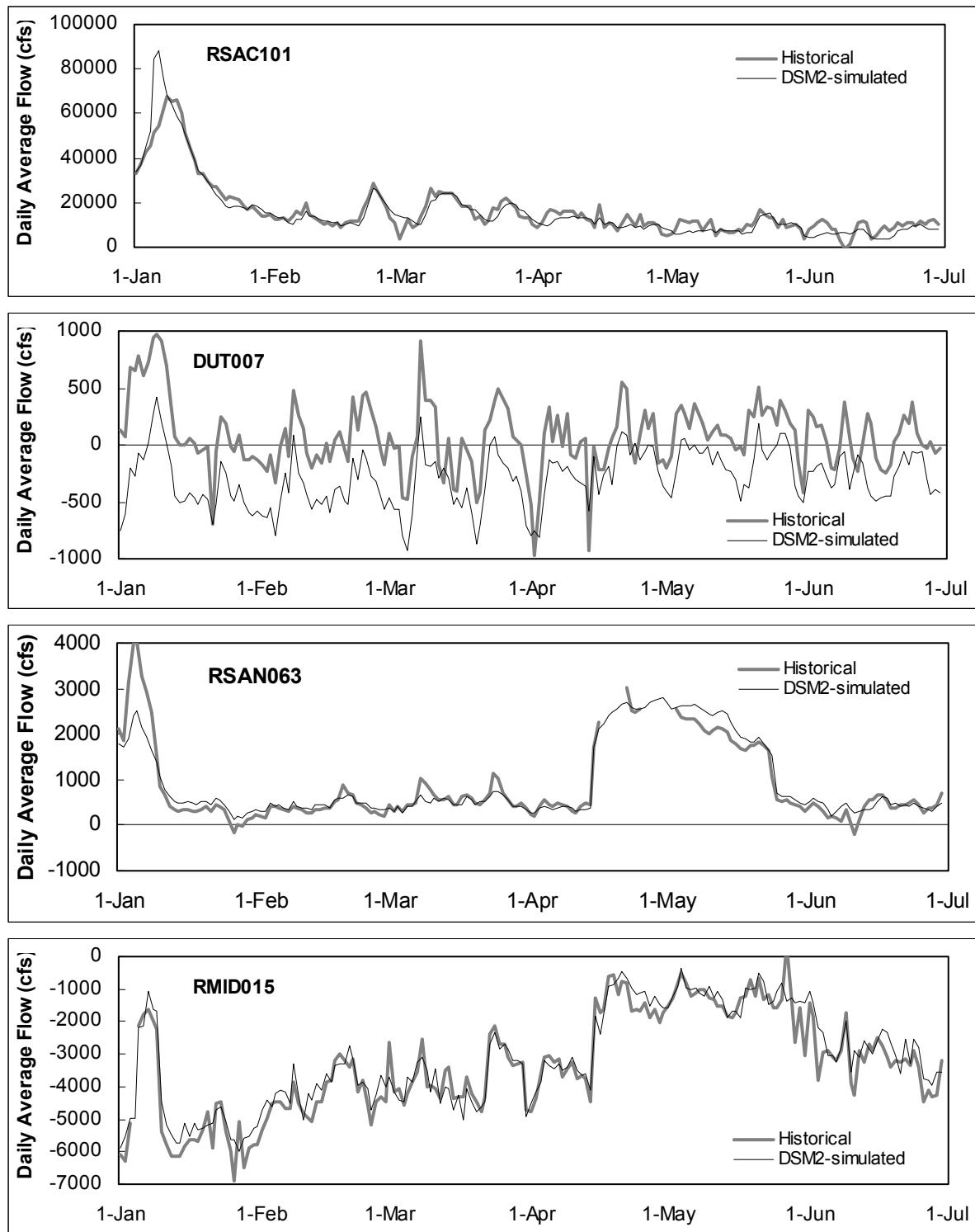


Figure 7. Historical and DSM2-simulated flow for Jan-Jul, 2002.

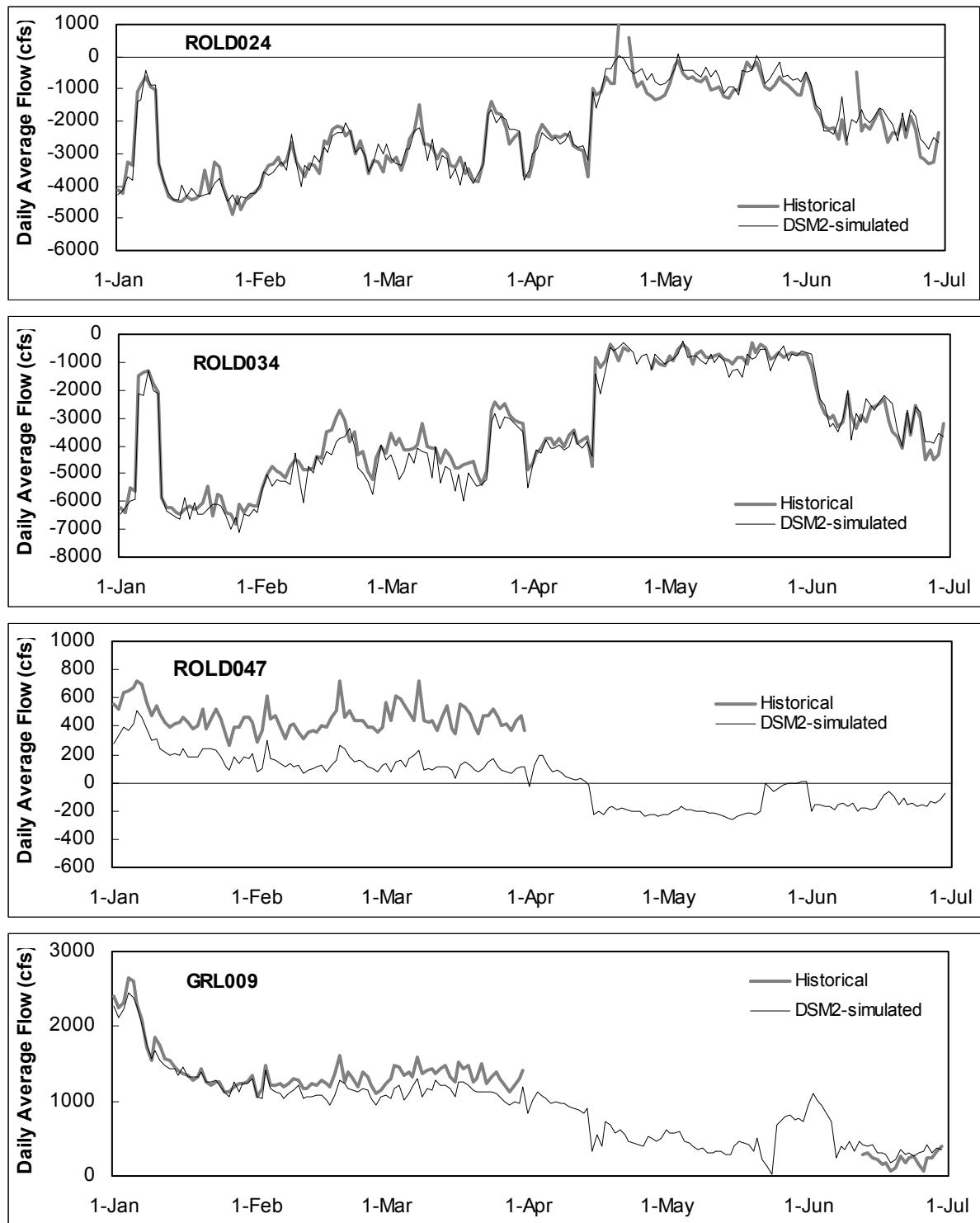


Figure 7 – cont. Historical and DSM2-simulated flow for Jan-Jul, 2002.

DSM2 Simulation of 2002 Hydrodynamics

In order to aid the interpretation of DSM2-simulated hydrodynamics, 2002 was broken up into 24 periods. These periods correspond to times for which significant Delta inflows and exports were fairly constant and south Delta barrier configurations were unchanging. These periods and their characteristics are shown in the table below.

Period		Period Average Flows				Period Barrier Status			
		Sac River + Yolo Bypass (cfs)	San Joaquin River (cfs)	DMC Pumping (cfs)	SWP Pumping (cfs)	MR	OR	GLC	ORH
JAN	1 - 4	52,468	4,849	4,044	8,012	--	--	--	--
	5 - 10	83,533	3,839	4,117	2,581	--	--	--	--
	11 - 31	30,316	1,968	4,172	7,268	--	--	--	--
FEB	1 - 28	18,238	1,895	3,601	4,941	--	--	--	--
MAR	1 - 22	21,846	2,121	4,149	4,630	--	--	--	--
	23 - 31	20,139	2,157	4,209	2,091	--	--	--	--
APR	1 - 14	16,321	1,822	3,501	3,986	--	--	--	--
	15 - 30	13,355	3,218	1,097	693	IN	IN	--	IN
MAY	1 - 24	12,694	3,000	836	573	IN	IN	--	IN
	25 - 31	15,098	2,107	922	805	IN	IN	--	--
JUN	1 - 6	12,653	1,676	3,267	1,580	IN	IN	--	--
	7 - 30	14,105	1,368	2,427	2,331	IN	IN	IN	--
JUL	1 - 31	18,817	1,275	4,348	6,222	IN	IN	IN	--
AUG	1 - 31	16,959	1,150	4,329	6,733	IN	IN	IN	--
SEP	1 - 30	13,554	1,161	4,278	4,131	IN	IN	IN	--
OCT	1 - 3	11,707	1,176	4,321	2,202	IN	IN	IN	--
	4 - 20	9,772	1,306	4,286	1,039	IN	IN	IN	IN
	21 - 31	9,709	2,069	3,698	2,665	IN	IN	IN	IN
NOV	1 - 10	11,913	1,669	2,626	2,196	IN	IN	IN	IN
	11 - 20	13,245	1,712	4,114	4,703	IN	IN	IN	IN
	21 - 28	11,161	1,493	4,254	2,628	IN/--	IN/--	IN/--	--
	29 - 30	21,960	1,411	4,264	2,153	--	--	--	--
DEC	1 - 13	11,406	1,425	3,346	2,063	--	--	--	--
	14 - 31	44,904	2,379	3,312	5,844	--	--	--	--

Table 3. Characteristics of intervals during 2002 for presentation of simulation results.

Hourly simulated stage and flow data for each period were used to generate data for box plots which graphically show period minimum, maximum, 25% quartile, 75% quartile, and average values. By typical sign convention, negative flow values correspond to upstream flow. The locations where box plots of stage and flow are presented are shown in Figure 8 with arrows indicating assumed positive flow direction. The numerical values these graphs are based upon are presented in the appendix to this report.

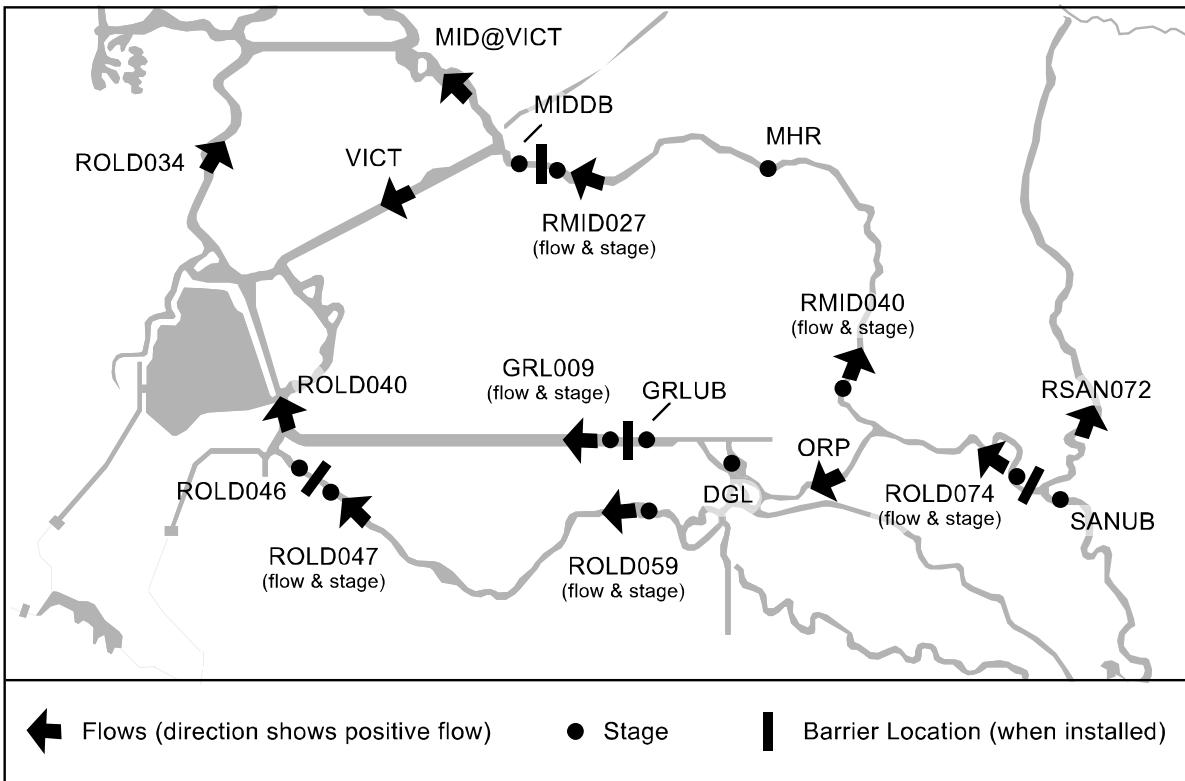


Figure 8. Locations where simulated Delta stages and flows for 2002 are presented.

The distributions of simulated stages and flow for each of the 24 intervals are shown in Figures 9 and 10. Stage results are presented upstream and downstream of each barrier location and flows are presented throughout the south Delta in order to convey the general circulation patterns. The minimum stages and the average flows from the distributions of data in Figures 9 and 10 are shown in Figure 11 which graphically presents the interaction between flow circulation and water levels caused by the installation of the south Delta barriers in 2002.

Discussion

The installation of the temporary barriers in 2002 significantly altered stages and flows in the south Delta. Minimum water levels tended to be raised 1 to 1½ feet in April and May in Middle and Old rivers upstream of the barriers, while minimum water levels immediately downstream of the barrier at the head of Old River fell about ½ foot due to the barrier here. Minimum water levels upstream of GRL009 did not improve until the barrier was installed here in June. Once all three agriculture barriers (Old River, Grant Line Canal, and Middle River) were installed, minimum stages upstream of the barriers further improved about ½ foot. These increases in minimum stage were consistent during the entire June 7 – November 20 period, even when the barrier at the head of Old River was in place from October 4 – November 20. This is probably due to a combination of the Grant Line Canal barrier remaining in place, raising water levels, and because the fall barrier at the head of Old River was notched at 0.0 msl.

In general, the installation of the temporary barriers also resulted in reduced tidal variation in flows near the barriers, a trend once again made more pronounced in Old

and Middle River with the installation of the barrier in Grant Line Canal. Each of the barriers still allowed some downstream flow, while both upstream and downstream flow was suppressed at each barrier site.

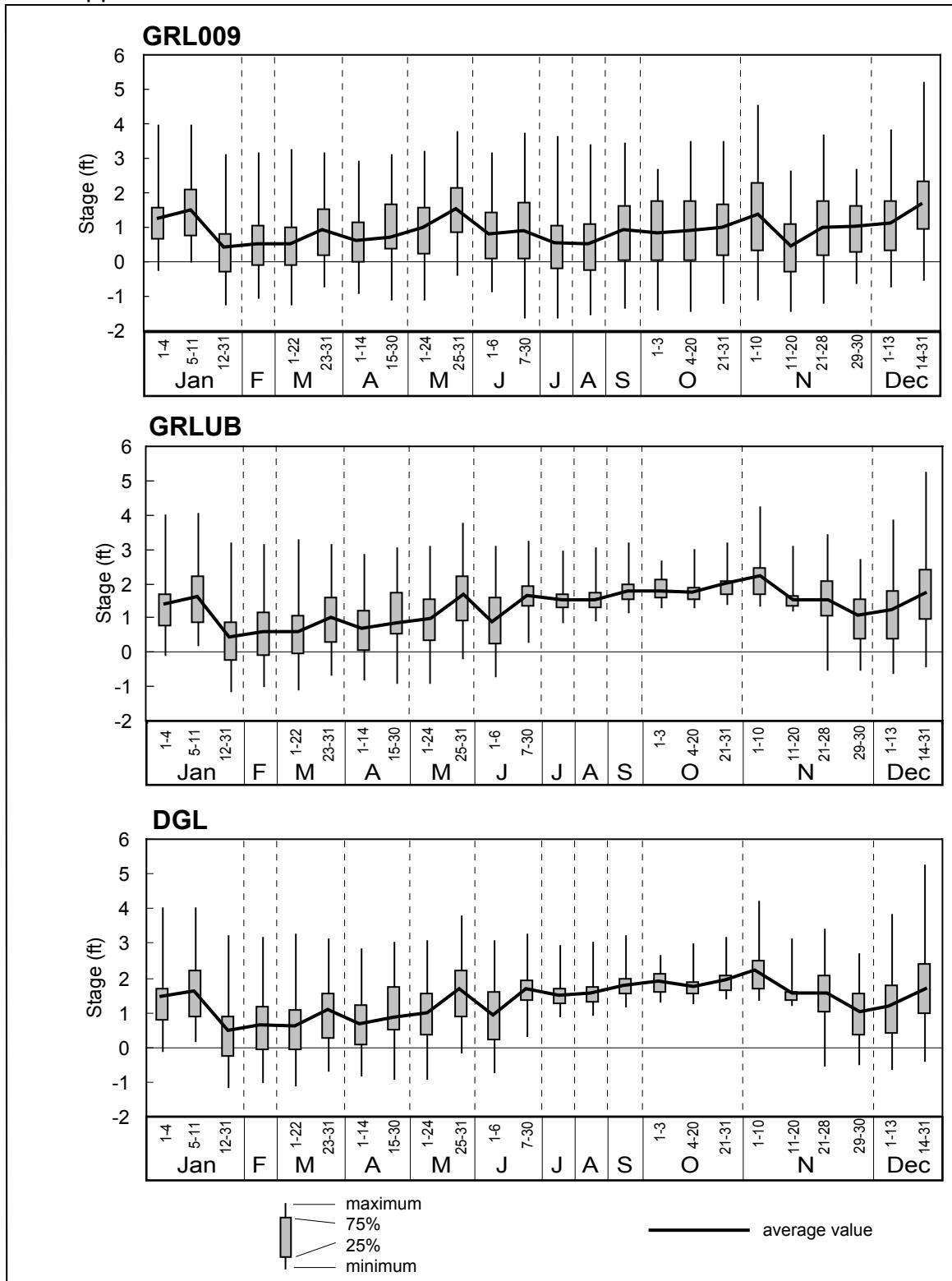


Figure 9. Box Plots showing distribution of DSM2-simulated stages for various periods during 2002.

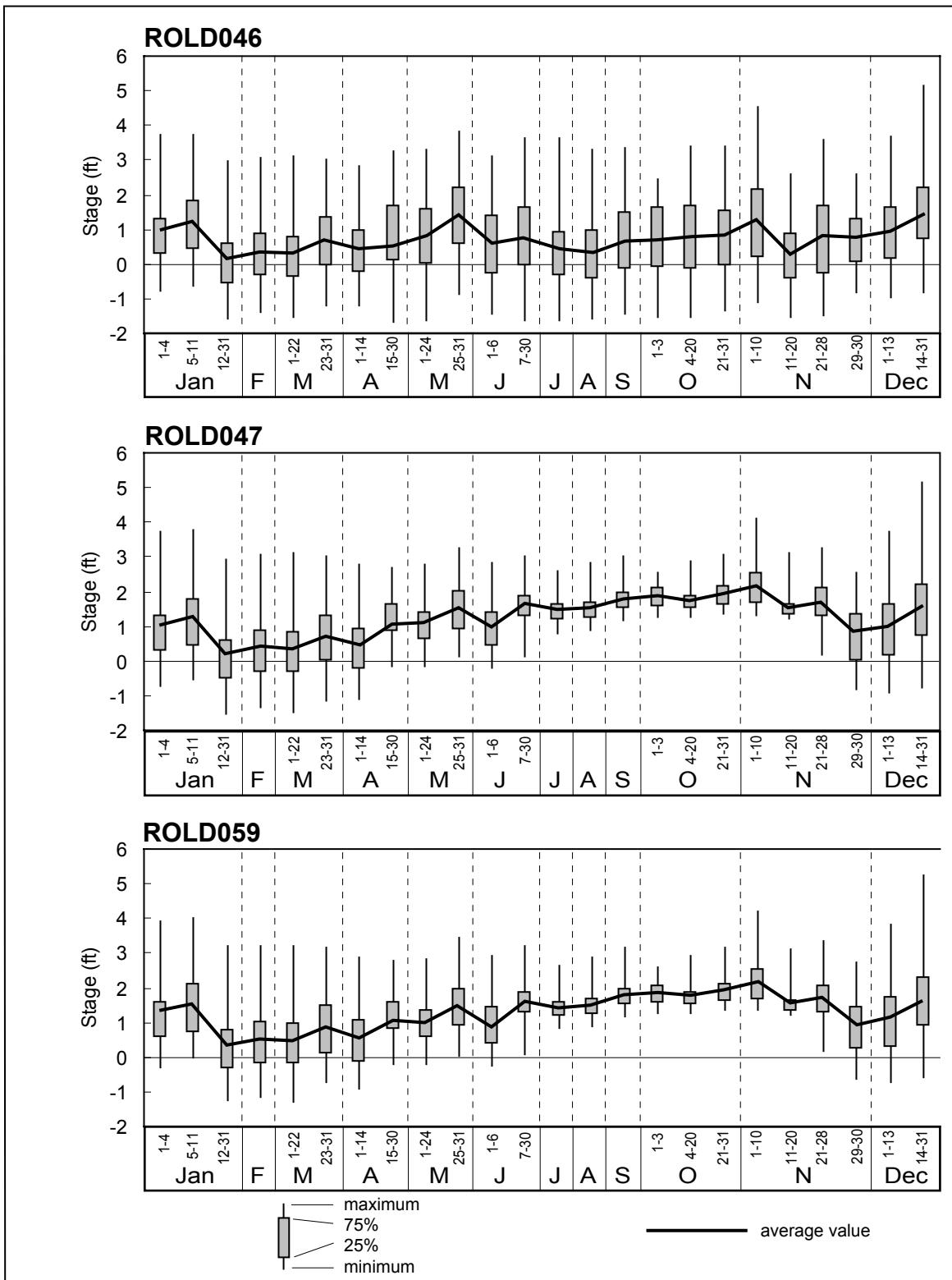


Figure 9 – cont. Box Plots showing distribution of DSM2-simulated stages for various periods during 2002.

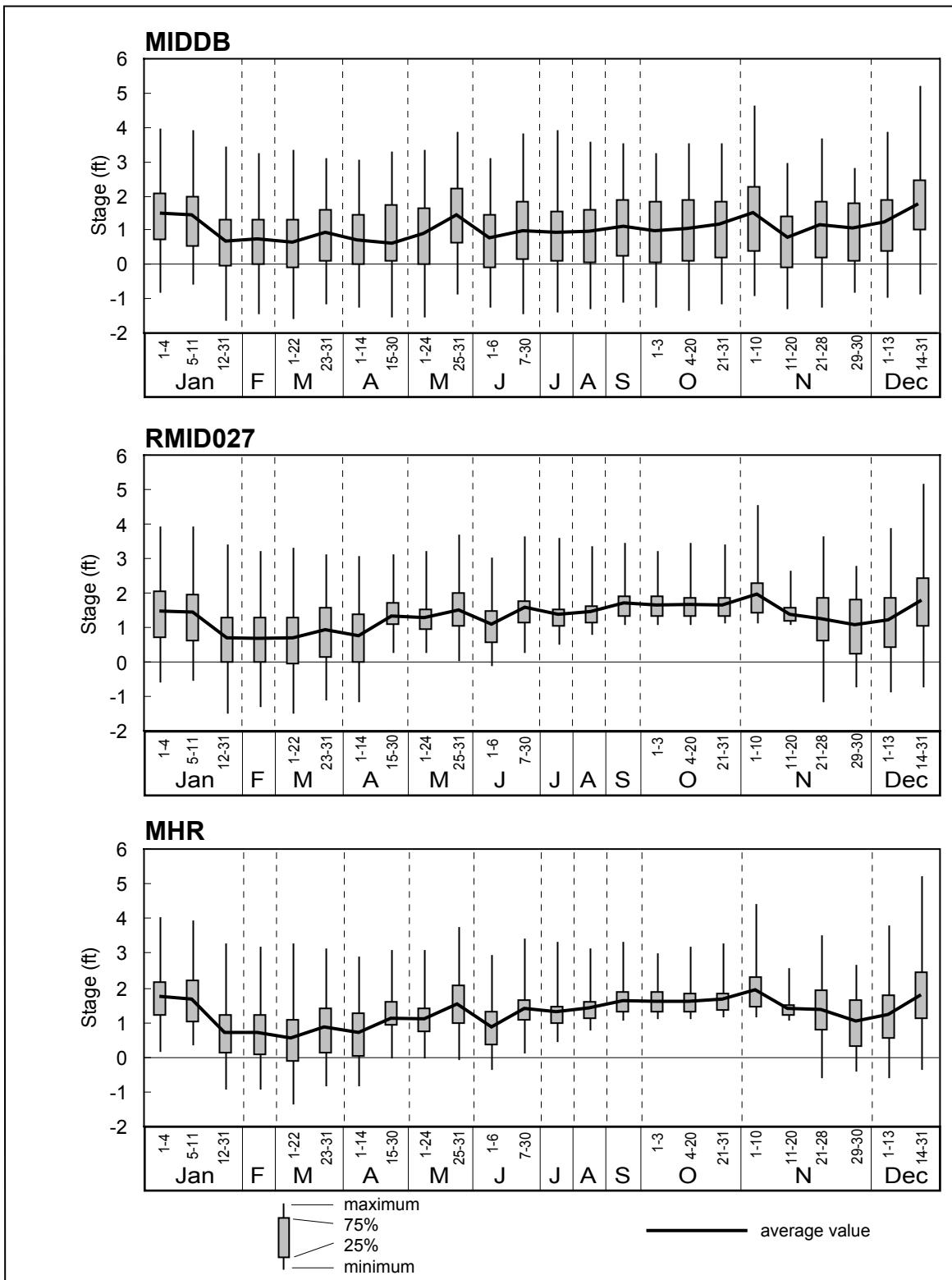


Figure 9 – cont. Box Plots showing distribution of DSM2-simulated stages for various periods during 2002.

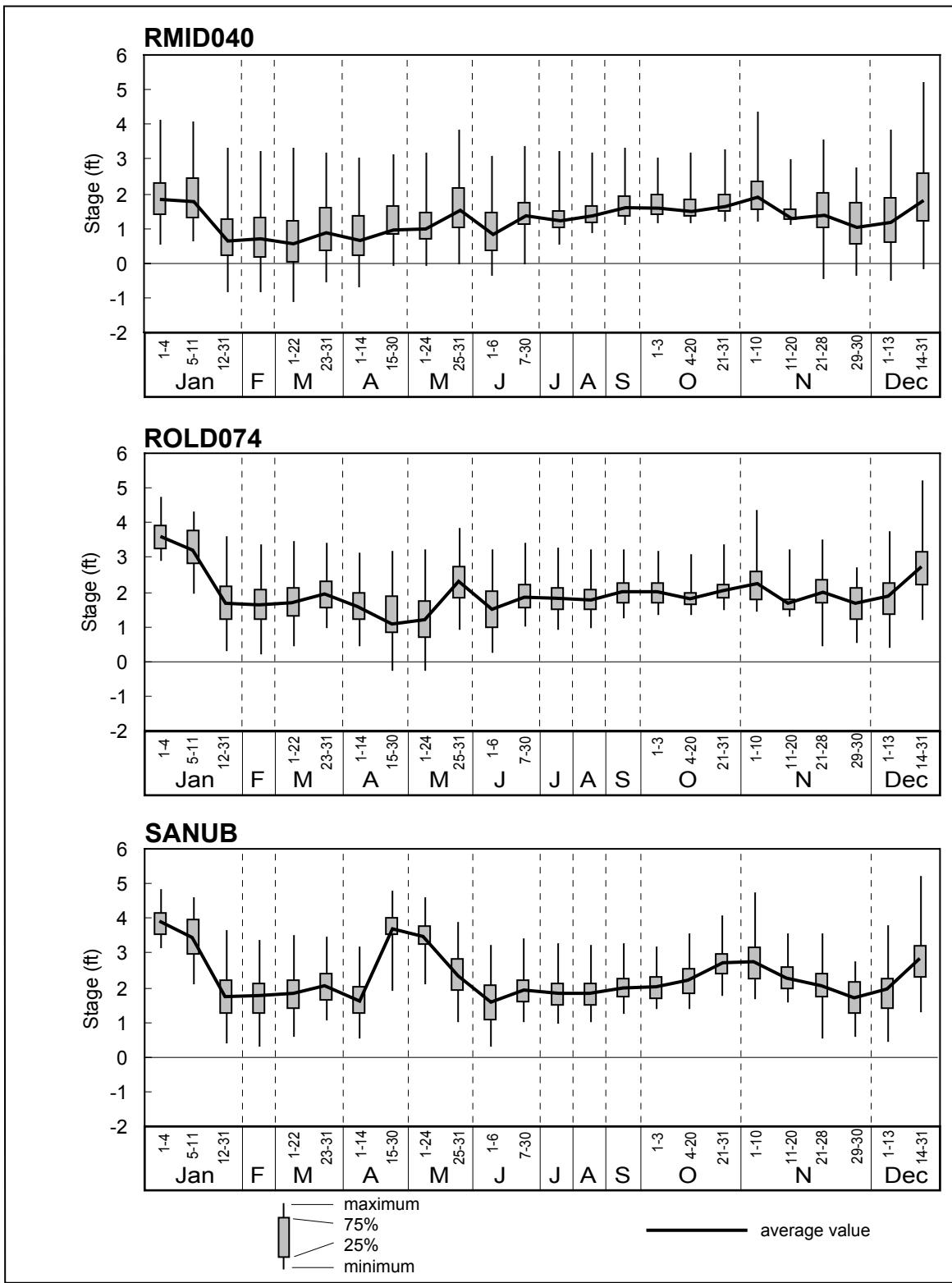


Figure 9 – cont. Box Plots showing distribution of DSM2-simulated stages for various periods during 2002.

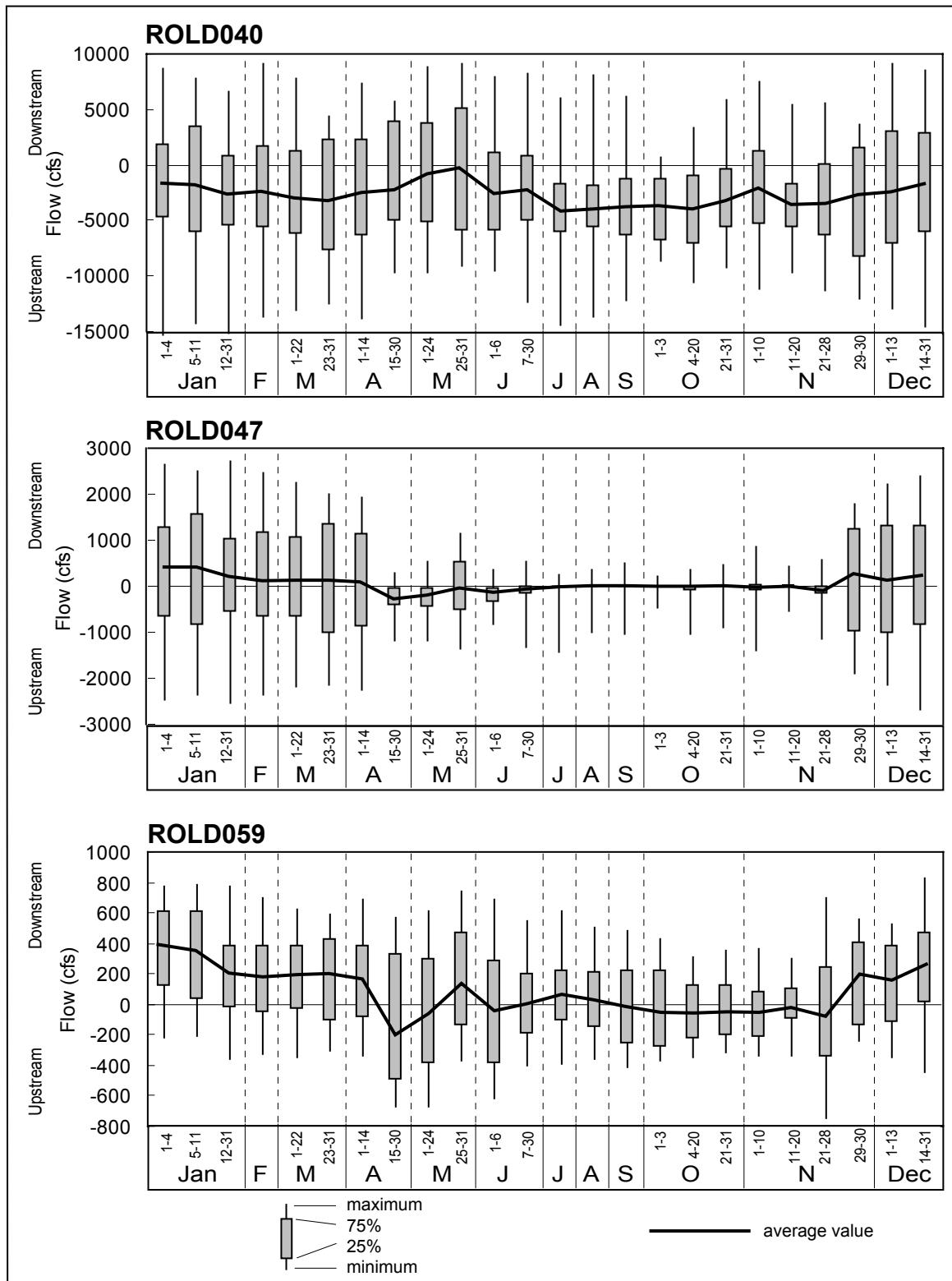


Figure 10. Box Plots showing distribution of DSM2-simulated flows for various periods during 2002.

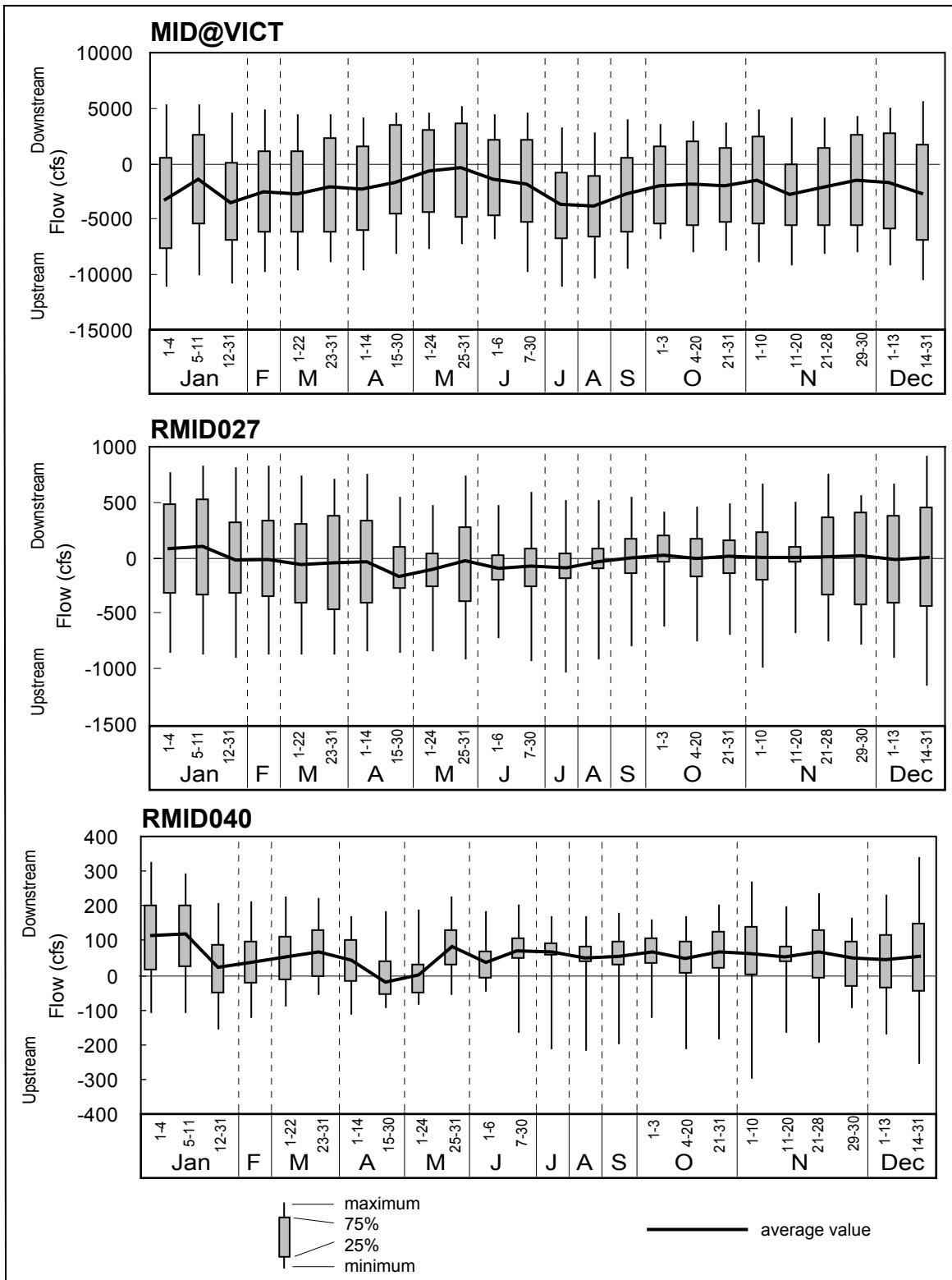


Figure 10 – cont. Box Plots showing distribution of DSM2-simulated flows for various periods during 2002.

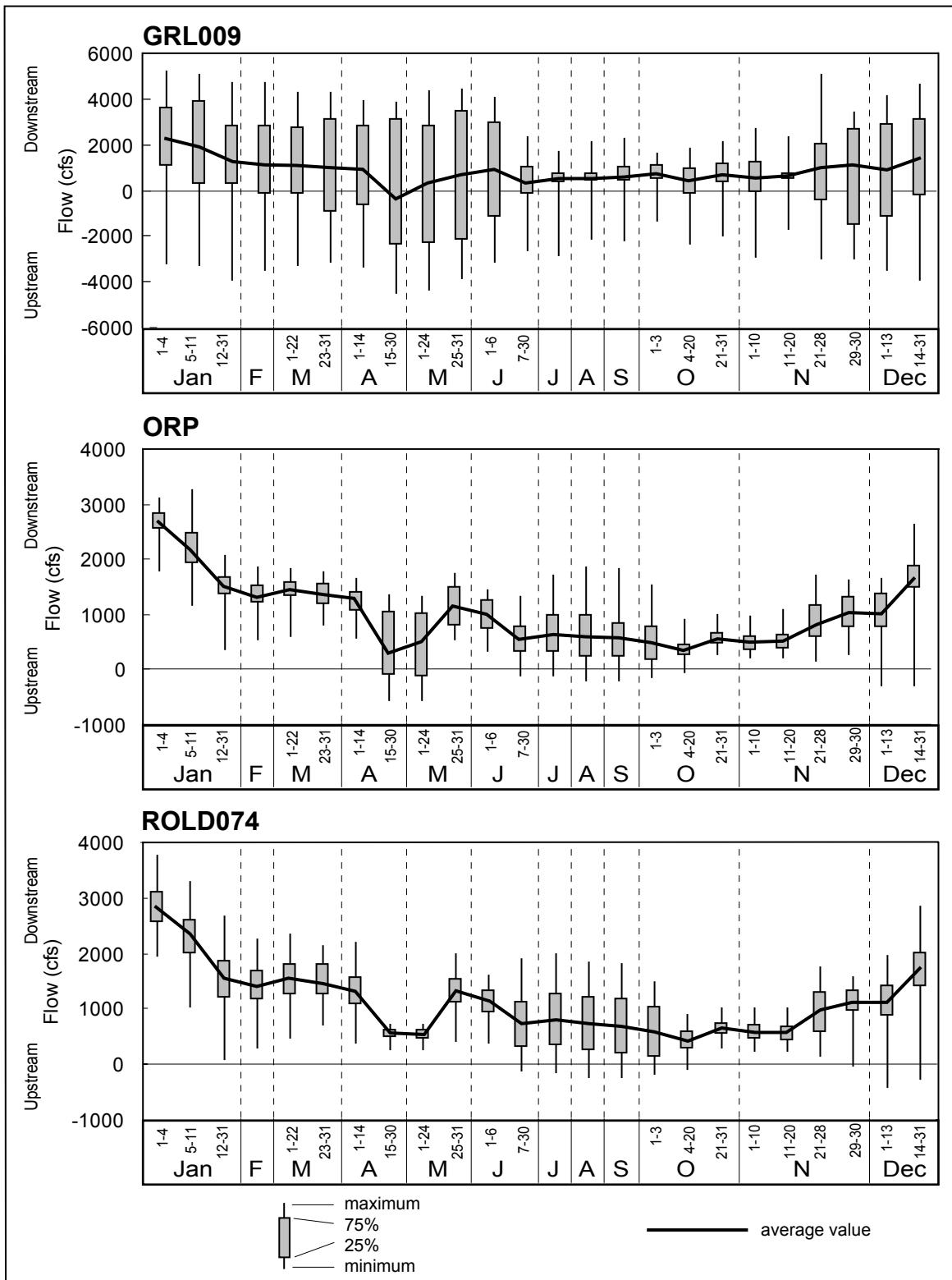


Figure 10 – cont. Box Plots showing distribution of DSM2-simulated flows for various periods during 2002.

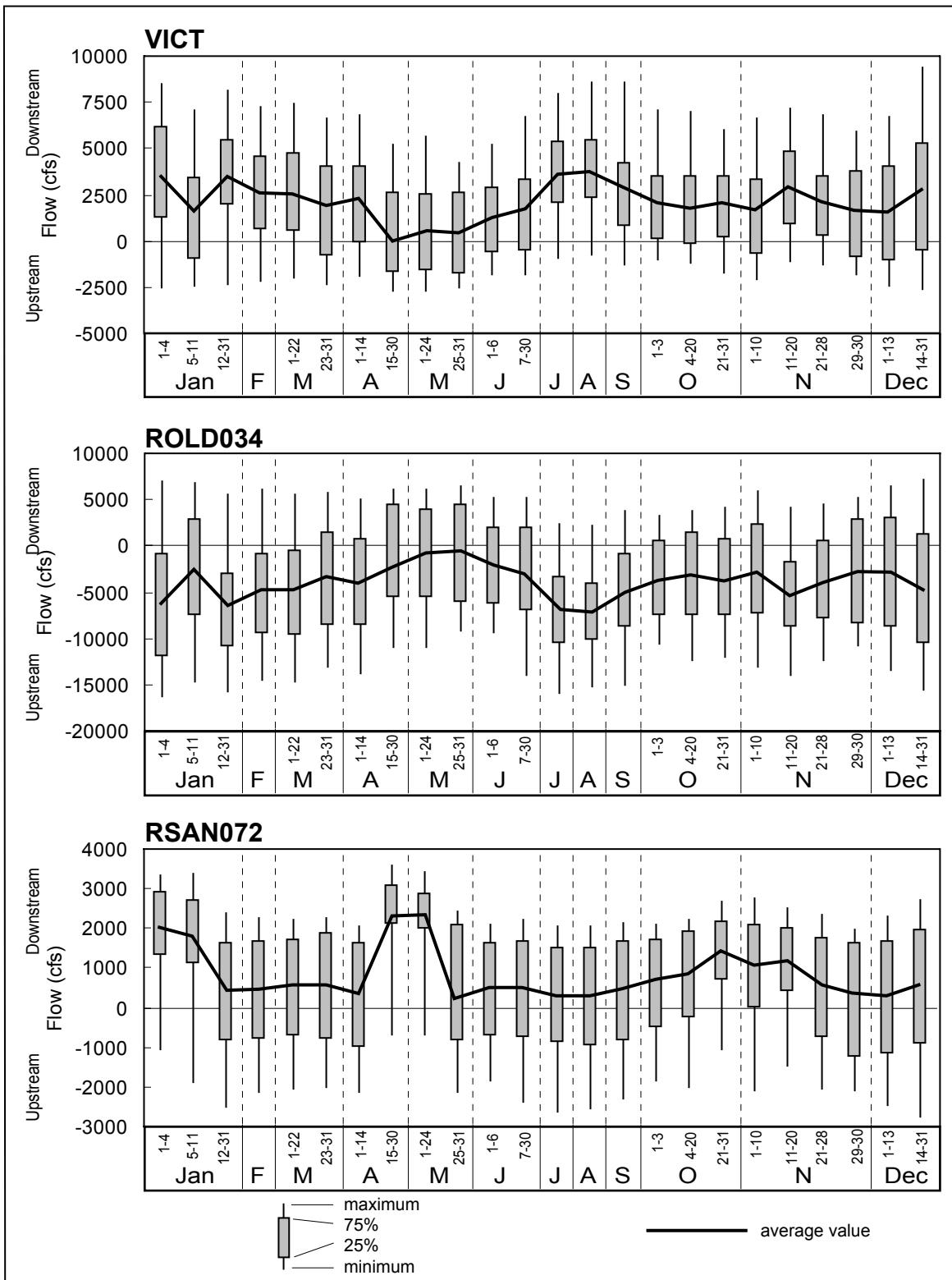


Figure 10 – cont. Box Plots showing distribution of DSM2-simulated flows for various periods during 2002.

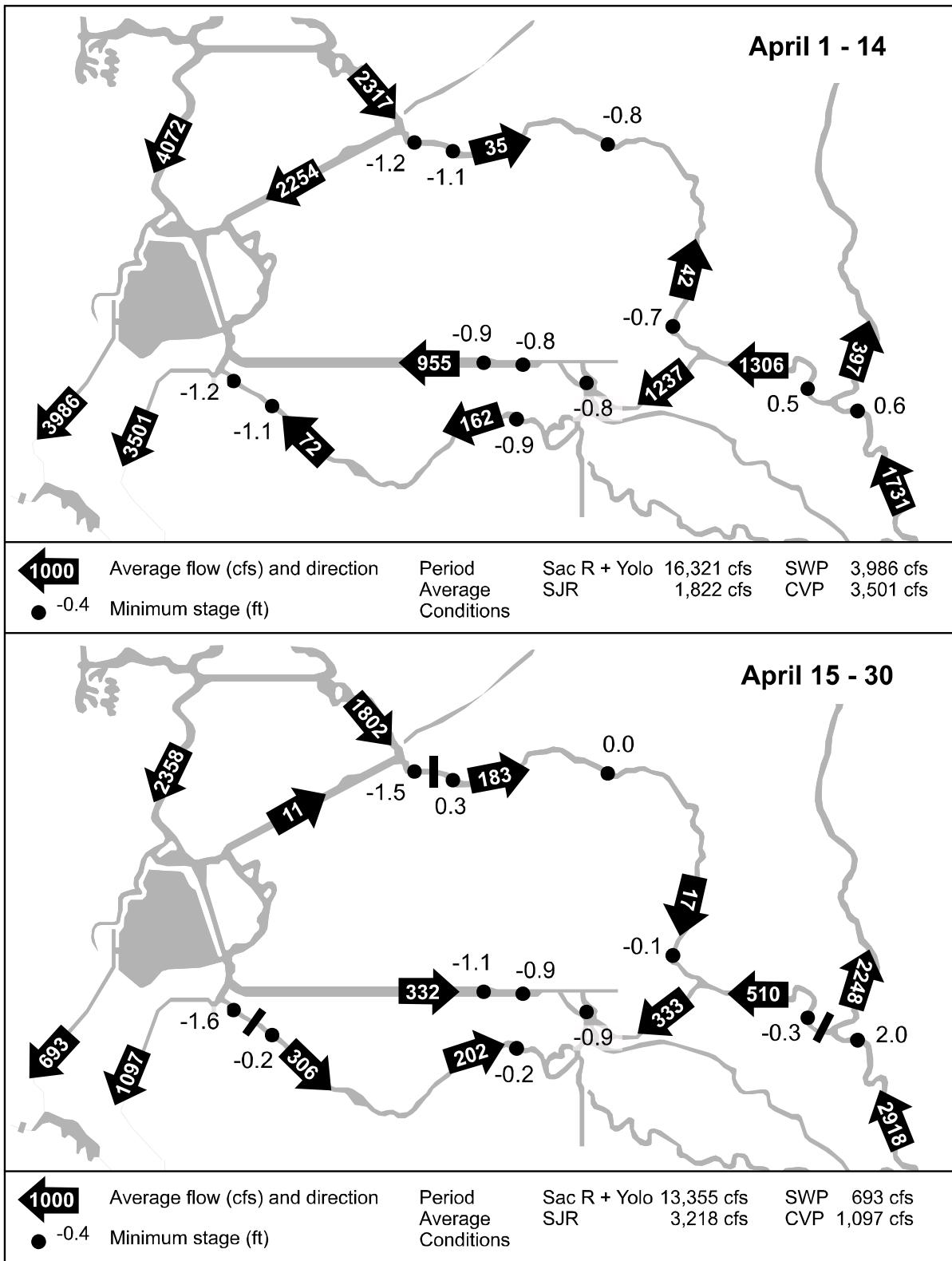


Figure 11. DSM2-simulated average flow patterns and minimum stages for 2002.

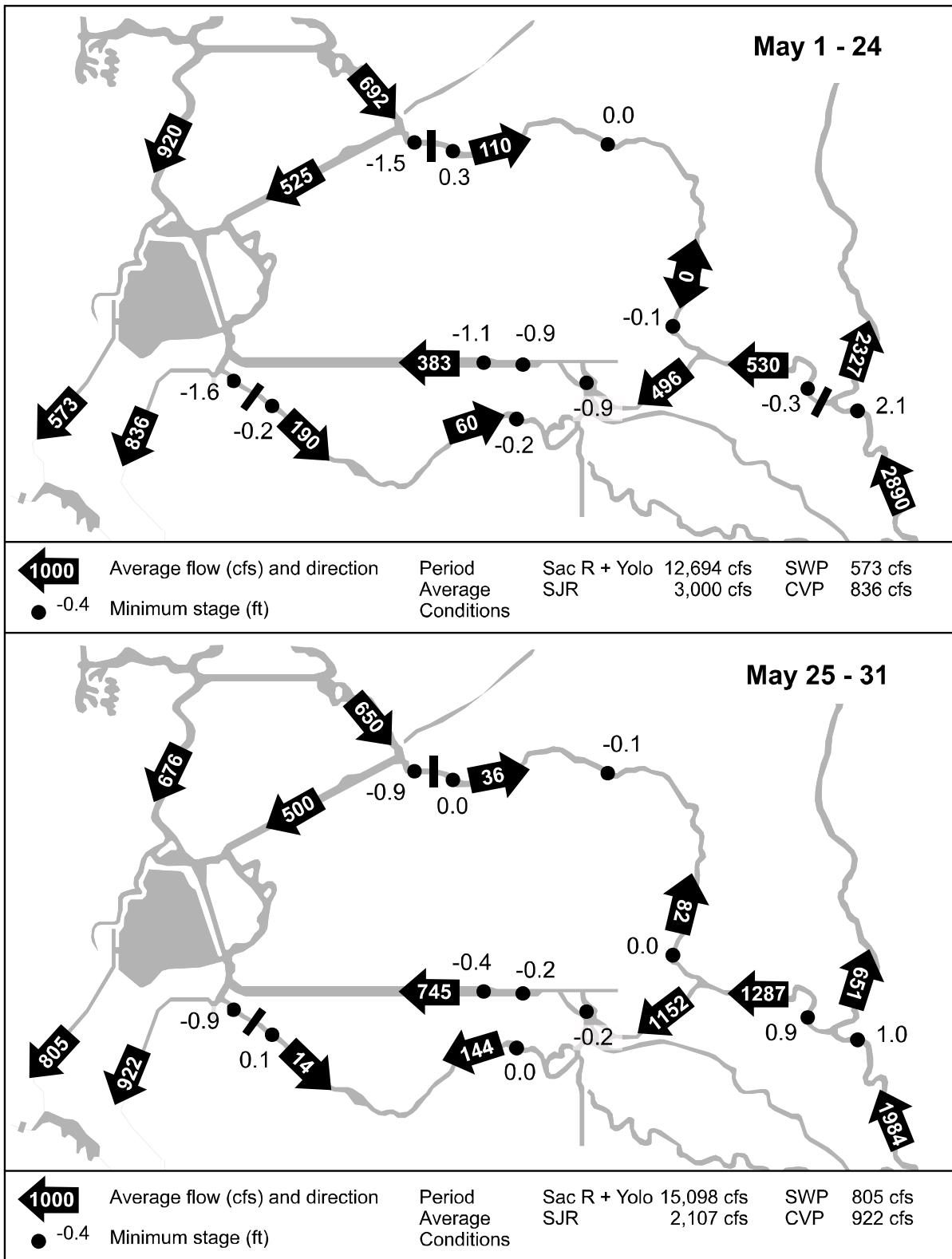


Figure 11 – cont. DSM2-simulated average flow patterns and minimum stages for 2002.

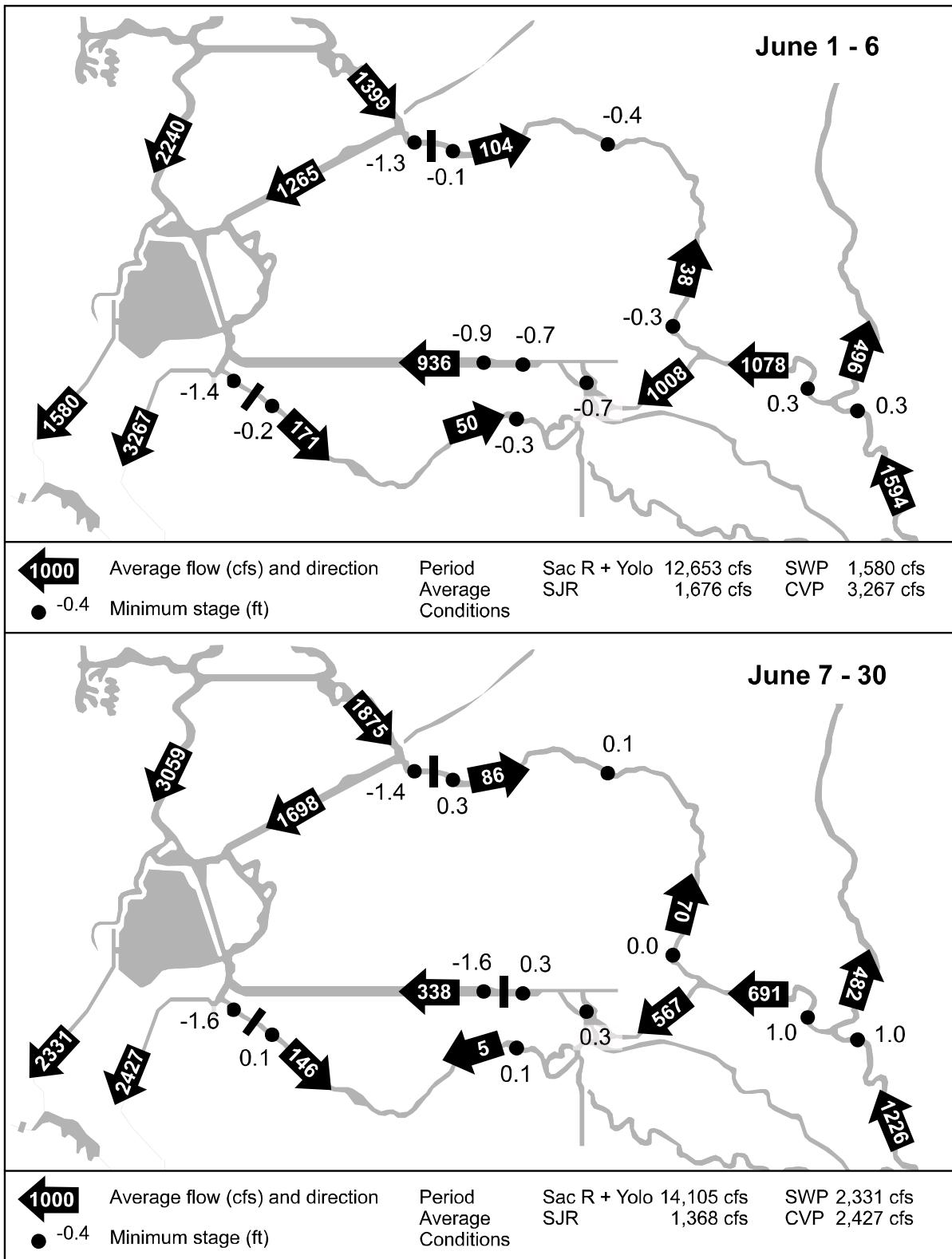


Figure 11 – cont. DSM2-simulated average flow patterns and minimum stages for 2002.

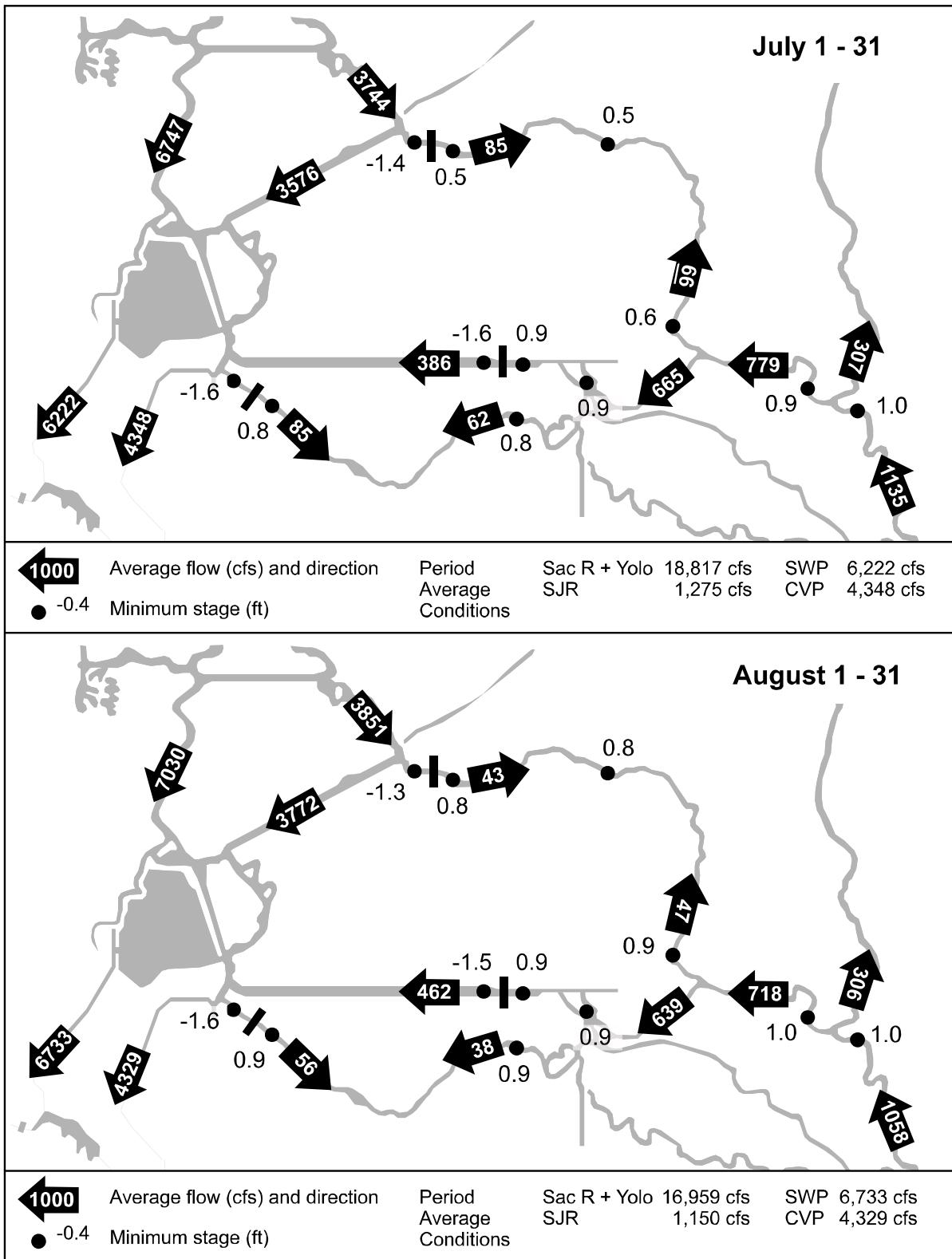


Figure 11 – cont. DSM2-simulated average flow patterns and minimum stages for 2002.

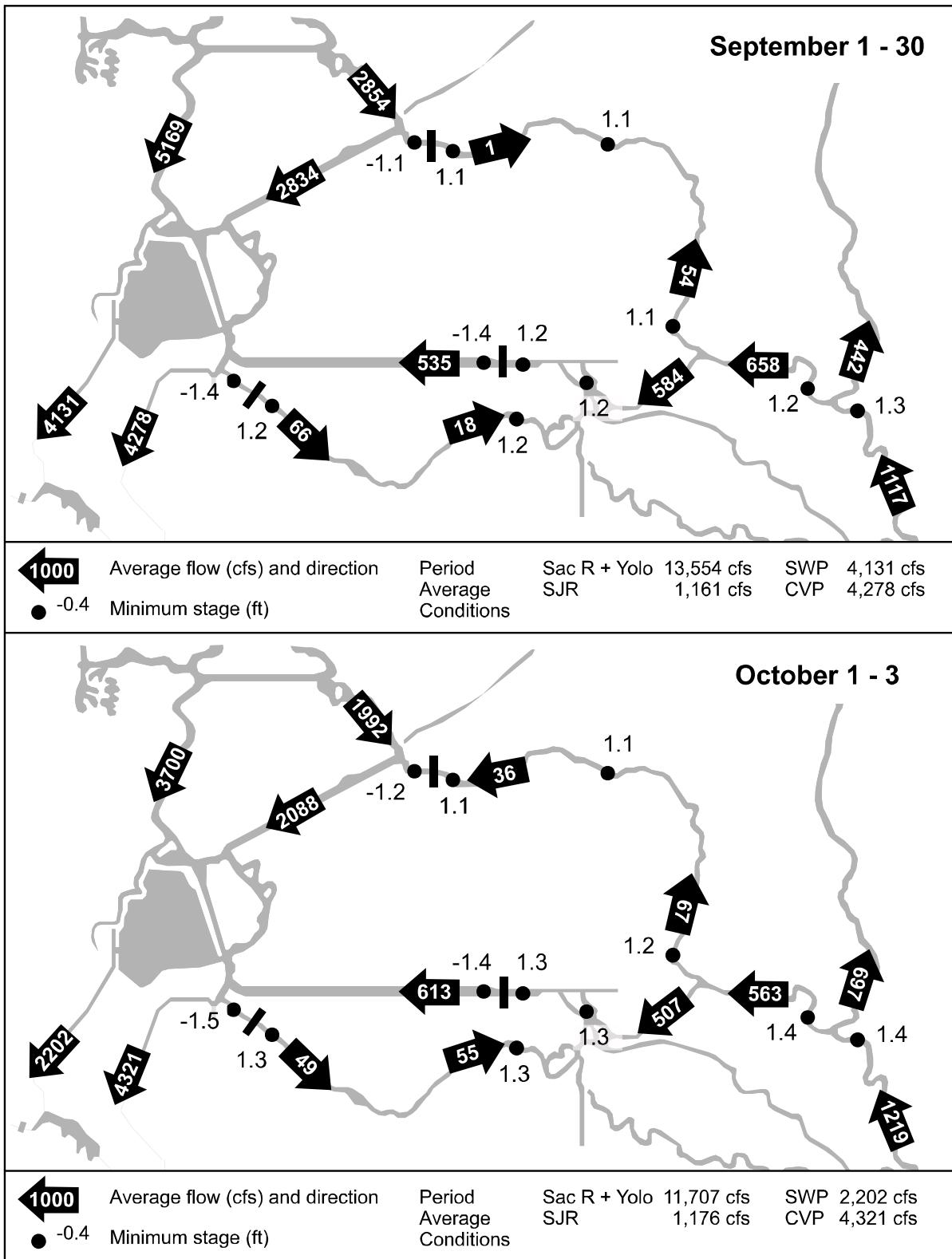


Figure 11 – cont. DSM2-simulated average flow patterns and minimum stages for 2002.

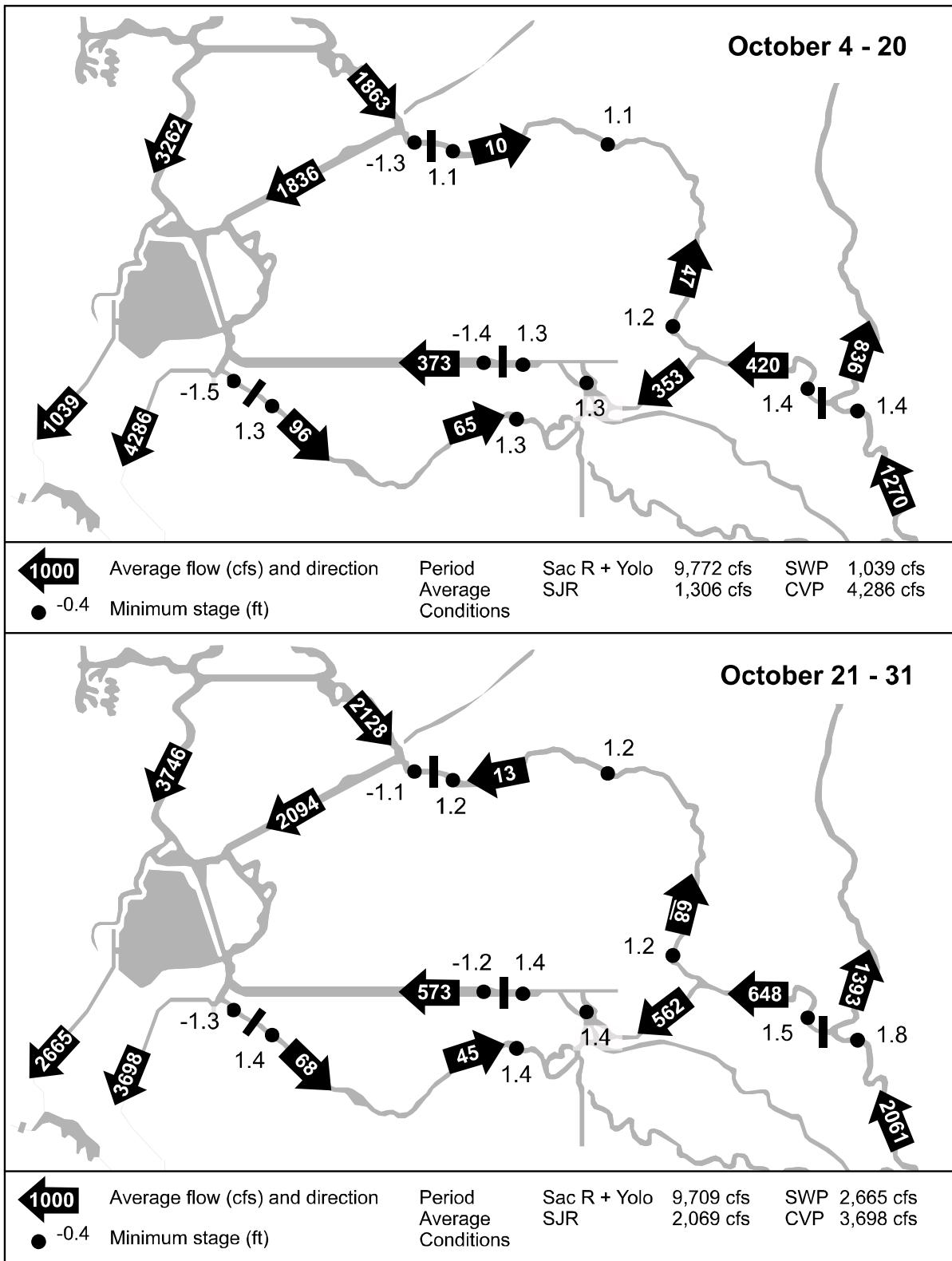


Figure 11 – cont. DSM2-simulated average flow patterns and minimum stages for 2002.

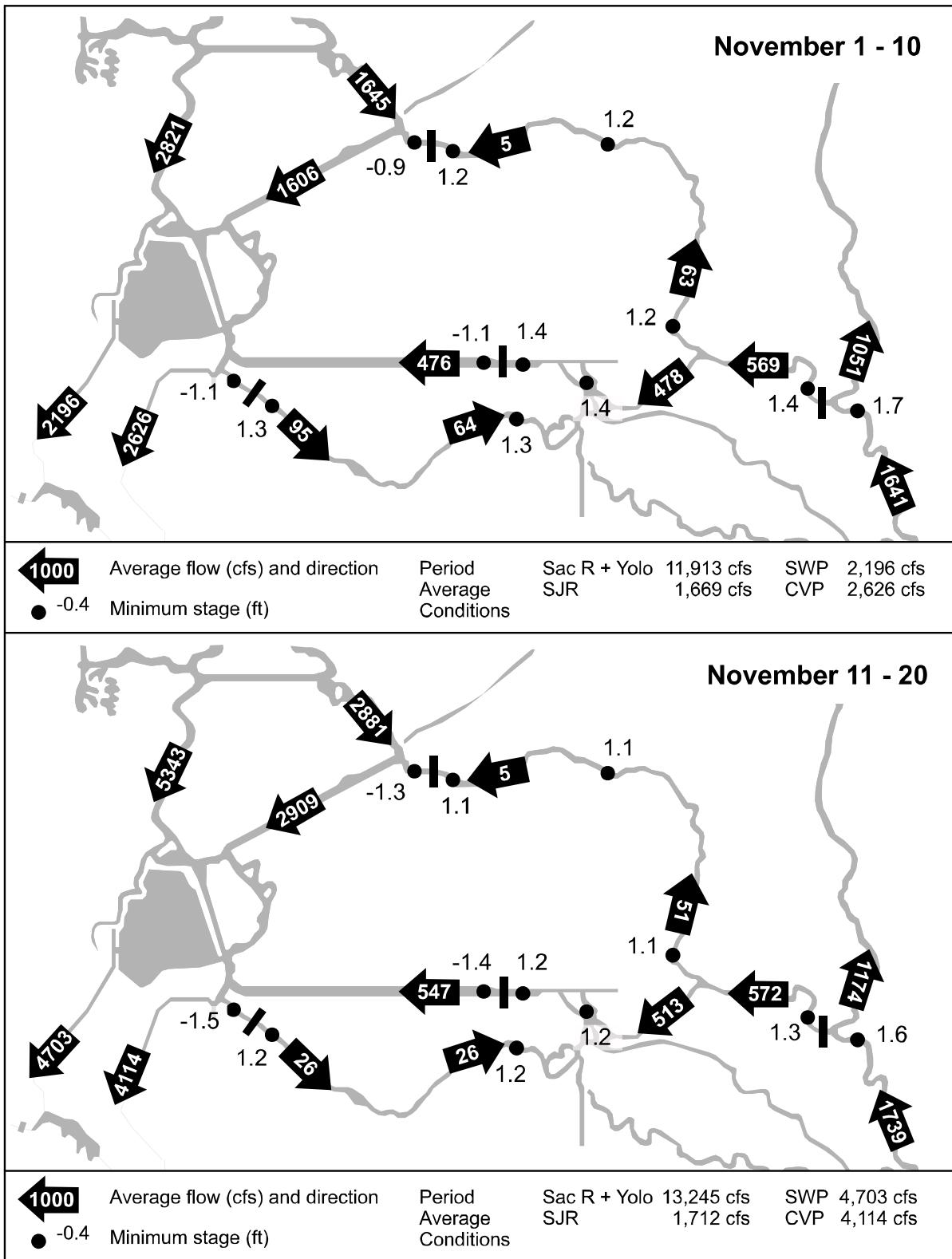


Figure 11 – cont. DSM2-simulated average flow patterns and minimum stages for 2002.

Appendix

This appendix consists of the stage and flow data that is presented graphically in this report via box plots. The values are derived from hourly simulated stage and flow over each of the 24 time periods.

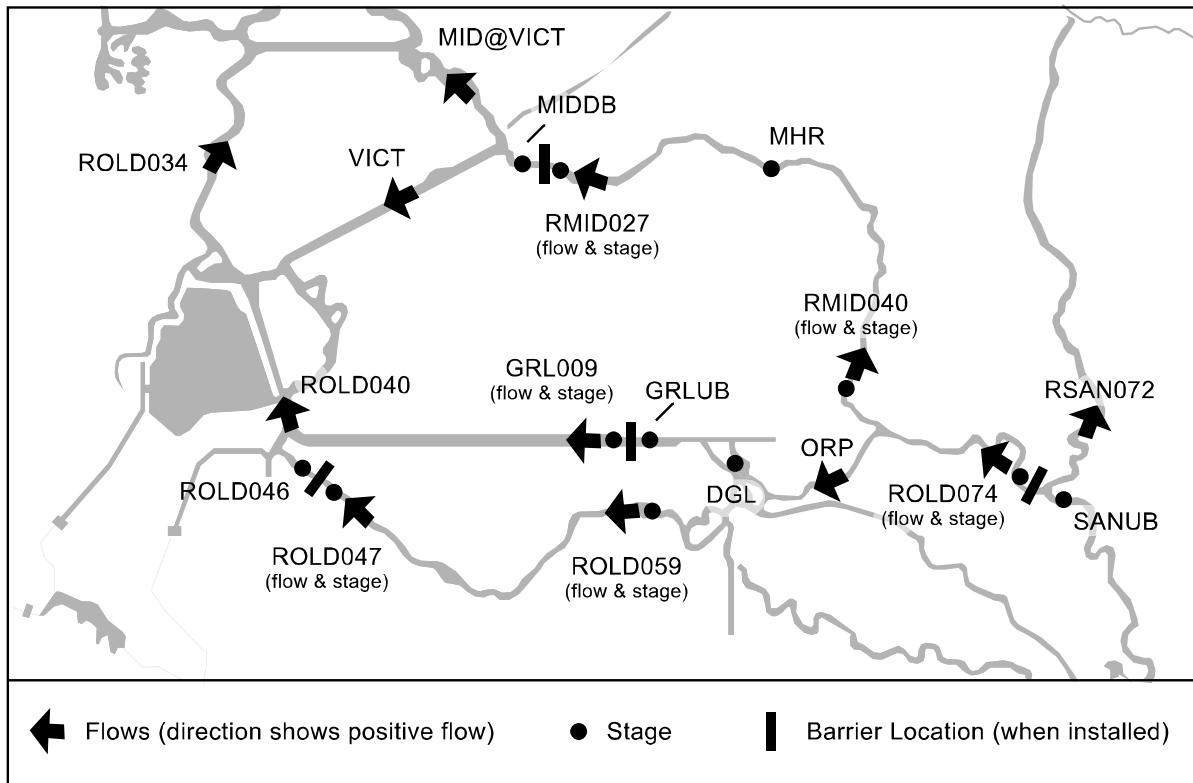


Figure A-1. Locations stage and flow data presented.

		Middle River at Howard Road (MHR)					RMID040					Doughty Cut Above Grantline Canal (DGL)				
		Min	25%	Avg	75%	Max	Min	25%	Avg	75%	Max	Min	25%	Avg	75%	Max
Jan	1 - 4	0.2	1.2	1.8	2.2	4.0	0.6	1.4	2.0	2.3	4.1	-0.1	0.7	1.4	1.7	4.0
	5 - 10	0.4	1.0	1.7	2.2	3.9	0.7	1.3	1.9	2.4	4.1	0.2	0.8	1.6	2.2	4.0
	11 - 31	-0.9	0.1	0.7	1.2	3.3	-0.8	0.2	0.8	1.3	3.3	-1.1	-0.3	0.4	0.9	3.2
Feb	1 - 28	-0.9	0.0	0.7	1.2	3.2	-0.8	0.2	0.8	1.3	3.2	-1.0	-0.1	0.6	1.2	3.1
Mar	1 - 22	-1.4	-0.2	0.5	1.1	3.3	-1.1	0.0	0.7	1.2	3.3	-1.1	-0.1	0.6	1.1	3.3
	23 - 31	-0.8	0.1	0.9	1.4	3.1	-0.5	0.3	1.0	1.6	3.1	-0.7	0.2	1.0	1.6	3.1
Apr	1 - 14	-0.8	0.0	0.7	1.3	2.9	-0.7	0.2	0.8	1.3	3.0	-0.8	0.0	0.7	1.2	2.8
	15 - 30	0.0	0.9	1.1	1.6	3.1	-0.1	0.8	1.1	1.7	3.1	-0.9	0.5	0.8	1.7	3.0
May	1 - 24	0.0	0.7	1.1	1.4	3.1	-0.1	0.6	1.1	1.5	3.2	-0.9	0.3	1.0	1.6	3.1
	25 - 31	-0.1	0.9	1.5	2.1	3.7	0.0	1.0	1.6	2.2	3.8	-0.2	0.9	1.6	2.2	3.8
Jun	1 - 6	-0.4	0.3	0.9	1.3	2.9	-0.3	0.3	0.9	1.4	3.0	-0.7	0.2	0.9	1.6	3.1
	7 - 30	0.1	1.0	1.4	1.7	3.4	0.0	1.1	1.5	1.7	3.4	0.3	1.3	1.7	1.9	3.2
Jul	1 - 31	0.5	0.9	1.3	1.5	3.3	0.6	1.0	1.3	1.5	3.2	0.9	1.2	1.5	1.7	2.9
Aug	1 - 31	0.8	1.1	1.4	1.6	3.1	0.9	1.1	1.5	1.7	3.2	0.9	1.3	1.5	1.8	3.0
Sep	1 - 30	1.1	1.3	1.6	1.9	3.3	1.1	1.3	1.7	1.9	3.3	1.2	1.5	1.8	2.0	3.2
Oct	1 - 3	1.1	1.3	1.6	1.9	3.0	1.2	1.4	1.7	2.0	3.0	1.3	1.5	1.8	2.1	2.7
	4 - 20	1.1	1.3	1.6	1.8	3.2	1.2	1.3	1.6	1.9	3.2	1.3	1.5	1.7	1.9	3.0
	21 - 31	1.2	1.3	1.7	1.9	3.3	1.2	1.4	1.8	2.0	3.2	1.4	1.6	1.9	2.1	3.2
Nov	1 - 10	1.2	1.4	1.9	2.3	4.4	1.2	1.5	2.0	2.4	4.4	1.4	1.6	2.1	2.5	4.2
	11 - 20	1.1	1.2	1.4	1.5	2.6	1.1	1.2	1.4	1.6	3.0	1.2	1.3	1.5	1.6	3.1
	21 - 28	-0.6	0.8	1.3	1.9	3.5	-0.5	1.0	1.5	2.0	3.5	-0.5	1.0	1.5	2.1	3.4
	29 - 30	-0.4	0.3	1.0	1.7	2.7	-0.4	0.5	1.2	1.7	2.7	-0.5	0.3	1.0	1.6	2.7
Dec	1 - 13	-0.6	0.5	1.2	1.8	3.8	-0.5	0.6	1.3	1.9	3.8	-0.6	0.4	1.2	1.8	3.8
	14 - 31	-0.3	1.1	1.8	2.5	5.2	-0.1	1.2	1.9	2.6	5.2	-0.4	0.9	1.7	2.4	5.2

Table A-1. Distribution of stages (feet) by study period.

		Grantline Canal US of Barrier Site (GRLUB)					ROLD046					ROLD047				
		Min	25%	Avg	75%	Max	Min	25%	Avg	75%	Max	Min	25%	Avg	75%	Max
Jan	1 - 4	-0.1	0.7	1.4	1.7	4.0	-0.8	0.3	1.0	1.3	3.7	-0.7	0.3	1.0	1.3	3.7
	5 - 10	0.2	0.8	1.6	2.2	4.0	-0.6	0.4	1.2	1.8	3.7	-0.5	0.4	1.2	1.8	3.8
	11 - 31	-1.1	-0.3	0.4	0.9	3.2	-1.6	-0.6	0.2	0.6	3.0	-1.5	-0.5	0.2	0.6	2.9
Feb	1 - 28	-1.0	-0.1	0.6	1.2	3.1	-1.4	-0.4	0.3	0.9	3.1	-1.3	-0.3	0.4	0.9	3.1
Mar	1 - 22	-1.1	-0.1	0.6	1.1	3.3	-1.5	-0.4	0.3	0.8	3.1	-1.5	-0.4	0.3	0.8	3.1
	23 - 31	-0.7	0.2	1.0	1.6	3.1	-1.2	0.0	0.7	1.3	3.0	-1.1	0.0	0.7	1.3	3.0
Apr	1 - 14	-0.8	0.0	0.7	1.2	2.8	-1.2	-0.3	0.4	1.0	2.8	-1.1	-0.3	0.4	0.9	2.8
	15 - 30	-0.9	0.5	0.8	1.7	3.0	-1.6	0.1	0.5	1.7	3.3	-0.2	0.8	1.0	1.7	2.7
May	1 - 24	-0.9	0.3	1.0	1.6	3.1	-1.6	0.0	0.8	1.6	3.3	-0.2	0.6	1.0	1.4	2.8
	25 - 31	-0.2	0.9	1.6	2.2	3.8	-0.9	0.6	1.4	2.2	3.8	0.1	0.9	1.5	2.0	3.3
Jun	1 - 6	-0.7	0.2	0.9	1.6	3.1	-1.4	-0.3	0.6	1.4	3.1	-0.2	0.4	0.9	1.4	2.8
	7 - 30	0.3	1.3	1.7	1.9	3.2	-1.6	-0.1	0.8	1.6	3.6	0.1	1.3	1.6	1.9	3.0
Jul	1 - 31	0.9	1.2	1.5	1.7	2.9	-1.6	-0.4	0.4	0.9	3.6	0.8	1.2	1.4	1.6	2.6
Aug	1 - 31	0.9	1.3	1.5	1.8	3.0	-1.6	-0.4	0.4	1.0	3.3	0.9	1.2	1.5	1.7	2.8
Sep	1 - 30	1.2	1.5	1.8	2.0	3.2	-1.4	-0.2	0.7	1.5	3.4	1.2	1.5	1.8	2.0	3.0
Oct	1 - 3	1.3	1.5	1.8	2.1	2.7	-1.5	-0.1	0.7	1.6	2.5	1.3	1.6	1.8	2.1	2.6
	4 - 20	1.3	1.5	1.7	1.9	3.0	-1.5	-0.1	0.8	1.7	3.4	1.3	1.5	1.7	1.9	2.9
	21 - 31	1.4	1.6	1.9	2.1	3.2	-1.3	-0.1	0.8	1.6	3.4	1.4	1.6	1.9	2.2	3.1
Nov	1 - 10	1.4	1.6	2.1	2.5	4.2	-1.1	0.2	1.2	2.2	4.5	1.3	1.7	2.1	2.6	4.1
	11 - 20	1.2	1.3	1.5	1.6	3.1	-1.5	-0.4	0.3	0.9	2.6	1.2	1.3	1.5	1.6	3.1
	21 - 28	-0.5	1.0	1.5	2.1	3.4	-1.5	-0.3	0.8	1.7	3.6	0.2	1.3	1.7	2.1	3.2
	29 - 30	-0.5	0.3	1.0	1.6	2.7	-0.8	0.0	0.8	1.3	2.6	-0.8	0.0	0.8	1.4	2.6
Dec	1 - 13	-0.6	0.4	1.2	1.8	3.8	-1.0	0.1	1.0	1.7	3.7	-0.9	0.1	1.0	1.6	3.7
	14 - 31	-0.4	0.9	1.7	2.4	5.2	-0.8	0.7	1.4	2.2	5.1	-0.8	0.7	1.5	2.2	5.1

Table A-1 – cont. Distribution of stages (feet) by study period.

		Middle River DS of Barrier Site (MIDDB)					GRL009					MID027				
		Min	25%	Avg	75%	Max	Min	25%	Avg	75%	Max	Min	25%	Avg	75%	Max
Jan	1 - 4	-0.8	0.7	1.4	2.1	3.9	-0.3	0.6	1.3	1.6	3.9	-0.6	0.7	1.4	2.1	3.9
	5 - 10	-0.6	0.5	1.3	2.0	3.9	0.0	0.7	1.5	2.1	3.9	-0.5	0.6	1.4	2.0	3.9
	11 - 31	-1.6	-0.1	0.6	1.3	3.4	-1.2	-0.3	0.4	0.8	3.1	-1.5	0.0	0.7	1.3	3.4
Feb	1 - 28	-1.4	-0.1	0.6	1.3	3.2	-1.0	-0.2	0.5	1.0	3.2	-1.3	0.0	0.7	1.3	3.2
Mar	1 - 22	-1.6	-0.2	0.6	1.3	3.3	-1.2	-0.2	0.5	1.0	3.2	-1.5	-0.1	0.6	1.3	3.3
	23 - 31	-1.1	0.1	0.9	1.6	3.1	-0.7	0.2	0.9	1.5	3.1	-1.1	0.1	0.9	1.6	3.1
Apr	1 - 14	-1.2	0.0	0.7	1.4	3.1	-0.9	0.0	0.6	1.1	2.9	-1.1	0.0	0.7	1.4	3.1
	15 - 30	-1.5	0.1	0.6	1.7	3.3	-1.1	0.3	0.7	1.7	3.1	0.3	1.0	1.2	1.7	3.1
May	1 - 24	-1.5	0.0	0.8	1.7	3.3	-1.1	0.2	0.9	1.6	3.2	0.3	0.9	1.3	1.5	3.2
	25 - 31	-0.9	0.6	1.4	2.2	3.8	-0.4	0.8	1.5	2.2	3.8	0.0	1.0	1.6	2.0	3.7
Jun	1 - 6	-1.3	-0.1	0.7	1.5	3.1	-0.9	0.0	0.8	1.4	3.1	-0.1	0.5	1.0	1.5	3.0
	7 - 30	-1.4	0.1	1.0	1.8	3.8	-1.6	0.0	0.9	1.7	3.7	0.3	1.1	1.5	1.8	3.6
Jul	1 - 31	-1.4	0.1	0.9	1.6	3.9	-1.6	-0.2	0.5	1.0	3.6	0.5	1.0	1.4	1.5	3.6
Aug	1 - 31	-1.3	0.0	0.9	1.6	3.6	-1.5	-0.3	0.5	1.1	3.4	0.8	1.1	1.5	1.6	3.4
Sep	1 - 30	-1.1	0.2	1.1	1.9	3.5	-1.4	0.0	0.8	1.6	3.4	1.1	1.3	1.7	1.9	3.4
Oct	1 - 3	-1.2	0.0	1.0	1.8	3.2	-1.4	0.0	0.8	1.8	2.7	1.1	1.3	1.7	1.9	3.2
	4 - 20	-1.3	0.0	1.0	1.9	3.5	-1.4	0.0	0.9	1.7	3.5	1.1	1.3	1.6	1.9	3.4
	21 - 31	-1.1	0.2	1.1	1.8	3.5	-1.2	0.2	1.0	1.7	3.5	1.2	1.3	1.7	1.8	3.4
Nov	1 - 10	-0.9	0.4	1.4	2.3	4.6	-1.1	0.3	1.3	2.3	4.5	1.2	1.4	1.9	2.3	4.5
	11 - 20	-1.3	-0.1	0.7	1.4	2.9	-1.4	-0.3	0.4	1.1	2.6	1.1	1.2	1.4	1.5	2.6
	21 - 28	-1.2	0.2	1.0	1.8	3.7	-1.2	0.1	1.0	1.8	3.7	-1.1	0.6	1.2	1.8	3.6
	29 - 30	-0.8	0.1	1.0	1.8	2.8	-0.6	0.2	1.0	1.6	2.7	-0.7	0.2	1.0	1.8	2.8
Dec	1 - 13	-1.0	0.4	1.2	1.9	3.9	-0.7	0.3	1.1	1.8	3.8	-0.8	0.4	1.2	1.9	3.8
	14 - 31	-0.8	1.0	1.7	2.5	5.2	-0.5	0.9	1.6	2.3	5.2	-0.7	1.0	1.7	2.4	5.2

Table A-1 – cont. Distribution of stages (feet) by study period.

		San Joaquin River Upstream of Barrier Site (SANUB)					ROLD059					ROLD074				
		Min	25%	Avg	75%	Max	Min	25%	Avg	75%	Max	Min	25%	Avg	75%	Max
Jan	1 - 4	3.2	3.5	3.9	4.2	4.8	-0.3	0.6	1.3	1.6	3.9	2.9	3.2	3.6	3.9	4.7
	5 - 10	2.1	2.9	3.4	4.0	4.6	0.0	0.7	1.5	2.1	4.0	2.0	2.8	3.2	3.8	4.3
	11 - 31	0.4	1.2	1.8	2.2	3.6	-1.3	-0.4	0.3	0.8	3.2	0.3	1.2	1.7	2.1	3.6
Feb	1 - 28	0.3	1.2	1.7	2.1	3.3	-1.1	-0.2	0.5	1.0	3.2	0.2	1.2	1.6	2.1	3.3
Mar	1 - 22	0.6	1.4	1.8	2.2	3.5	-1.3	-0.2	0.4	1.0	3.2	0.5	1.3	1.7	2.1	3.4
	23 - 31	1.1	1.6	2.0	2.4	3.4	-0.7	0.1	0.8	1.5	3.2	1.0	1.5	2.0	2.3	3.4
Apr	1 - 14	0.6	1.2	1.6	2.0	3.2	-0.9	-0.1	0.5	1.1	2.9	0.5	1.2	1.6	2.0	3.1
	15 - 30	2.0	3.5	3.5	4.0	4.8	-0.2	0.8	1.0	1.6	2.8	-0.3	0.8	1.1	1.9	3.2
May	1 - 24	2.1	3.2	3.4	3.8	4.6	-0.2	0.5	1.0	1.4	2.8	-0.3	0.6	1.2	1.7	3.2
	25 - 31	1.0	1.9	2.4	2.8	3.9	0.0	0.9	1.5	2.0	3.5	0.9	1.8	2.3	2.7	3.8
Jun	1 - 6	0.3	1.0	1.6	2.1	3.2	-0.3	0.4	0.9	1.4	2.9	0.3	1.0	1.5	2.0	3.2
	7 - 30	1.0	1.5	1.9	2.2	3.4	0.1	1.3	1.6	1.9	3.2	1.0	1.5	1.9	2.2	3.4
Jul	1 - 31	1.0	1.5	1.8	2.1	3.3	0.8	1.2	1.4	1.6	2.6	0.9	1.4	1.8	2.1	3.2
Aug	1 - 31	1.0	1.5	1.8	2.1	3.2	0.9	1.2	1.5	1.7	2.9	1.0	1.4	1.8	2.1	3.2
Sep	1 - 30	1.3	1.7	2.0	2.3	3.3	1.2	1.5	1.8	2.0	3.1	1.2	1.6	2.0	2.2	3.2
Oct	1 - 3	1.4	1.7	2.0	2.3	3.2	1.3	1.6	1.8	2.1	2.6	1.4	1.6	2.0	2.2	3.1
	4 - 20	1.4	1.8	2.2	2.5	3.5	1.3	1.5	1.7	1.9	2.9	1.4	1.6	1.8	2.0	3.0
	21 - 31	1.8	2.4	2.7	3.0	4.1	1.4	1.6	1.9	2.1	3.2	1.5	1.8	2.0	2.2	3.4
Nov	1 - 10	1.7	2.2	2.8	3.2	4.7	1.3	1.7	2.1	2.5	4.2	1.4	1.8	2.2	2.6	4.3
	11 - 20	1.6	1.9	2.3	2.6	3.5	1.2	1.3	1.5	1.6	3.1	1.3	1.4	1.7	1.8	3.2
	21 - 28	0.6	1.7	2.0	2.4	3.5	0.2	1.3	1.7	2.1	3.4	0.5	1.6	2.0	2.4	3.5
	29 - 30	0.6	1.2	1.7	2.2	2.7	-0.6	0.2	0.9	1.5	2.8	0.6	1.2	1.7	2.1	2.7
Dec	1 - 13	0.5	1.4	1.9	2.3	3.8	-0.7	0.3	1.1	1.7	3.8	0.4	1.3	1.8	2.3	3.7
	14 - 31	1.3	2.3	2.8	3.2	5.2	-0.6	0.9	1.6	2.3	5.2	1.2	2.1	2.7	3.2	5.2

Table A-1 – cont. Distribution of stages (feet) by study period.

		ROLD059					ROLD047					RMID040				
		Min	25%	Avg	75%	Max	Min	25%	Avg	75%	Max	Min	25%	Avg	75%	Max
Jan	1 - 4	-221	112	389	615	769	-2461	-670	367	1276	2646	-107	12	114	200	326
	5 - 10	-206	30	358	617	784	-2370	-845	401	1554	2515	-107	20	119	201	290
	11 - 31	-357	-19	204	386	769	-2551	-561	193	1051	2732	-153	-54	22	87	205
Feb	1 - 28	-331	-52	173	383	695	-2346	-683	141	1175	2472	-121	-28	40	98	211
Mar	1 - 22	-345	-34	185	388	626	-2184	-693	116	1084	2256	-86	-15	52	109	223
	23 - 31	-309	-113	195	429	588	-2135	-1047	114	1361	1991	-54	-9	67	129	222
Apr	1 - 14	-333	-86	162	383	682	-2235	-882	72	1154	1931	-112	-21	42	101	166
	15 - 30	-670	-495	-202	333	568	-1191	-440	-306	-36	298	-91	-59	-17	39	183
May	1 - 24	-670	-394	-60	304	608	-1191	-453	-190	-33	532	-82	-54	0	30	185
	25 - 31	-373	-147	144	474	737	-1340	-533	-14	540	1132	-55	28	82	132	223
Jun	1 - 6	-614	-389	-50	294	692	-826	-348	-171	-32	356	-47	-11	38	69	183
	7 - 30	-406	-198	5	204	549	-1335	-194	-146	-10	547	-166	43	70	107	200
Jul	1 - 31	-387	-112	62	219	613	-1432	-23	-85	5	260	-209	56	66	92	169
Aug	1 - 31	-353	-157	38	216	507	-983	-22	-56	8	358	-216	33	47	81	169
Sep	1 - 30	-415	-256	-18	228	477	-1040	-24	-66	11	513	-196	24	54	98	179
Oct	1 - 3	-364	-279	-55	227	433	-470	-22	-49	10	208	-119	30	67	104	158
	4 - 20	-347	-225	-65	122	309	-1022	-98	-96	-10	352	-210	1	47	99	170
	21 - 31	-312	-206	-45	123	357	-895	-18	-68	6	480	-183	15	68	124	201
Nov	1 - 10	-335	-221	-64	81	366	-1396	-114	-95	42	868	-297	-4	63	137	265
	11 - 20	-333	-102	-26	101	294	-539	-12	-26	2	427	-164	34	51	81	198
	21 - 28	-747	-345	-85	249	703	-1139	-170	-95	3	580	-191	-11	68	128	234
	29 - 30	-236	-144	195	408	563	-1906	-1013	255	1240	1773	-92	-34	45	99	165
Dec	1 - 13	-348	-122	151	387	528	-2152	-1020	131	1310	2202	-167	-41	42	114	231
	14 - 31	-448	6	259	475	832	-2676	-852	247	1336	2396	-252	-48	54	150	338

Table A-2 Distribution of flows (cfs) by study period.

		VICT					GRL009					ROLD034				
		Min	25%	Avg	75%	Max	Min	25%	Avg	75%	Max	Min	25%	Avg	75%	Max
Jan	1 - 4	-2501	1198	3459	6225	8481	-3189	1048	2263	3651	5195	-16337	-11975	-6164	-831	6980
	5 - 10	-2469	-1008	1597	3415	7098	-3282	247	1945	3921	5086	-14672	-7494	-2596	2950	6808
	11 - 31	-2309	1891	3473	5515	8133	-3923	238	1303	2805	4741	-15723	-10979	-6432	-2996	5484
Feb	1 - 28	-2172	609	2547	4586	7223	-3477	-163	1111	2845	4712	-14408	-9544	-4741	-798	6168
Mar	1 - 22	-1946	506	2613	4784	7428	-3250	-190	1150	2777	4269	-14631	-9672	-4902	-451	5631
	23 - 31	-2298	-862	1922	4055	6634	-3142	-942	1066	3118	4284	-13089	-8654	-3423	1405	5719
Apr	1 - 14	-1855	-80	2254	4037	6826	-3306	-696	955	2848	3938	-13864	-8640	-4072	777	5104
	15 - 30	-2672	-1750	-11	2610	5243	-4523	-2406	-332	3152	3874	-11002	-5656	-2358	4496	6139
May	1 - 24	-2672	-1640	525	2508	5687	-4379	-2333	383	2825	4345	-10925	-5583	-920	3977	6100
	25 - 31	-2486	-1773	500	2645	4248	-3859	-2192	745	3516	4414	-9127	-6117	-676	4520	6364
Jun	1 - 6	-1818	-642	1265	2919	5235	-3107	-1216	936	2958	4084	-9364	-6255	-2240	2021	5126
	7 - 30	-1829	-522	1698	3317	6698	-2634	-162	338	1047	2327	-13906	-7066	-3059	1959	5221
Jul	1 - 31	-940	1989	3576	5387	7936	-2808	337	386	739	1711	-15864	-10544	-6747	-3372	2334
Aug	1 - 31	-765	2238	3772	5512	8564	-2128	391	462	757	2147	-15231	-10274	-7030	-4051	2205
Sep	1 - 30	-1253	745	2834	4236	8589	-2176	430	535	1023	2237	-15064	-8747	-5169	-847	3830
Oct	1 - 3	-1006	86	2088	3500	7087	-1305	456	613	1130	1583	-10680	-7544	-3700	623	3228
	4 - 20	-1159	-163	1836	3497	7015	-2314	-195	373	980	1807	-12405	-7574	-3262	1423	3738
	21 - 31	-1698	104	2094	3525	5993	-1970	342	573	1158	2141	-11985	-7598	-3746	836	4217
Nov	1 - 10	-2041	-703	1606	3335	6660	-2883	-73	476	1281	2670	-13135	-7458	-2821	2339	5978
	11 - 20	-1138	865	2909	4886	7179	-1655	472	547	738	2342	-13921	-8767	-5343	-1747	4140
	21 - 28	-1261	241	2158	3545	6772	-2986	-440	938	2018	5056	-12314	-7917	-3900	554	4451
	29 - 30	-1779	-874	1683	3787	5934	-3007	-1525	1007	2725	3393	-10792	-8495	-2875	2923	5169
Dec	1 - 13	-2389	-1074	1651	4030	6751	-3457	-1167	816	2918	4110	-13365	-8802	-2874	3038	6531
	14 - 31	-2580	-547	2740	5293	9335	-3893	-262	1341	3093	4624	-15590	-10504	-4857	1225	7190

Table A-2 cont. Distribution of flows (cfs) by study period.

		ORP					ROLD074					MID at VICT				
		Min	25%	Avg	75%	Max	Min	25%	Avg	75%	Max	Min	25%	Avg	75%	Max
Jan	1 - 4	1790	2541	2676	2838	3107	1965	2550	2804	3114	3762	-11018	-7688	-3430	460	5319
	5 - 10	1170	1928	2207	2470	3242	1031	1996	2313	2616	3296	-9979	-5541	-1417	2598	5303
	11 - 31	369	1356	1505	1683	2079	106	1202	1537	1859	2661	-10764	-6968	-3488	22	4493
Feb	1 - 28	545	1199	1326	1520	1843	293	1155	1389	1688	2266	-9740	-6215	-2600	1164	4807
Mar	1 - 22	618	1333	1418	1580	1836	468	1250	1504	1810	2337	-9572	-6312	-2700	1079	4438
	23 - 31	824	1177	1368	1556	1765	716	1236	1481	1800	2142	-8716	-6226	-2003	2262	4452
Apr	1 - 14	580	1067	1237	1424	1655	379	1063	1306	1584	2186	-9570	-6149	-2317	1511	4014
	15 - 30	-565	-115	333	1062	1356	275	466	510	637	718	-8019	-4600	-1802	3457	4528
May	1 - 24	-565	-137	496	1027	1328	275	450	530	622	715	-7547	-4501	-692	3118	4514
	25 - 31	533	790	1152	1496	1743	406	1095	1287	1544	1976	-7207	-4957	-650	3616	5050
Jun	1 - 6	352	729	1008	1250	1436	376	923	1078	1326	1617	-6759	-4839	-1399	2123	4316
	7 - 30	-95	323	567	790	1332	-103	301	691	1140	1888	-9653	-5428	-1875	2197	4569
Jul	1 - 31	-109	298	665	1003	1708	-127	328	779	1264	1978	-10948	-6790	-3744	-725	3258
Aug	1 - 31	-184	231	639	989	1861	-231	229	718	1232	1854	-10254	-6718	-3851	-1159	2738
Sep	1 - 30	-185	220	584	853	1828	-229	182	658	1192	1824	-9422	-6312	-2854	576	3912
Oct	1 - 3	-123	154	507	784	1543	-160	115	563	1036	1475	-6688	-5518	-1992	1611	3438
	4 - 20	-52	245	353	447	901	-90	263	420	589	887	-7972	-5716	-1863	1954	3845
	21 - 31	285	453	562	665	1001	299	540	648	753	1013	-7821	-5446	-2128	1387	3700
Nov	1 - 10	225	340	478	601	971	235	449	569	705	1011	-8803	-5569	-1645	2429	4800
	11 - 20	215	372	513	623	1071	232	422	572	684	1019	-9009	-5734	-2881	-10	4059
	21 - 28	148	591	867	1174	1721	162	560	950	1320	1745	-8023	-5732	-2195	1418	4080
	29 - 30	265	762	1055	1320	1607	-18	965	1082	1339	1583	-7919	-5651	-1561	2620	4159
Dec	1 - 13	-289	758	1017	1375	1660	-394	878	1082	1427	1971	-9049	-6022	-1706	2804	5026
	14 - 31	-278	1465	1637	1873	2623	-265	1410	1714	2025	2857	-10465	-6947	-2770	1769	5515

Table A-2 cont. Distribution of flows (cfs) by study period.

		RMID027					RSAN072					ROLDO40				
		Min	25%	Avg	75%	Max	Min	25%	Avg	75%	Max	Min	25%	Avg	75%	Max
Jan	1 - 4	-850	-326	83	478	762	-1049	1312	1986	2908	3322	-15255	-4813	-1557	1874	8709
	5 - 10	-858	-353	106	525	823	-1902	1084	1758	2715	3387	-14208	-6110	-1701	3448	7763
	11 - 31	-895	-329	-8	318	809	-2490	-826	448	1643	2372	-15141	-5570	-2691	815	6549
Feb	1 - 28	-859	-357	-21	341	825	-2111	-819	464	1695	2247	-13732	-5696	-2396	1778	9068
Mar	1 - 22	-861	-414	-58	305	731	-2049	-718	540	1716	2235	-13084	-6213	-2921	1271	7766
	23 - 31	-859	-474	-50	372	706	-1992	-791	586	1890	2243	-12524	-7778	-3114	2337	4405
Apr	1 - 14	-837	-418	-35	337	742	-2146	-1005	397	1655	2056	-13789	-6446	-2495	2255	7385
	15 - 30	-842	-291	-183	97	541	-701	2104	2248	3085	3566	-9635	-5118	-2138	3957	5767
May	1 - 24	-839	-265	-110	42	471	-701	1950	2327	2901	3409	-9635	-5168	-686	3740	8802
	25 - 31	-909	-402	-36	280	730	-2136	-860	651	2074	2408	-9053	-6000	-344	5091	9178
Jun	1 - 6	-712	-220	-104	18	469	-1825	-720	496	1635	2077	-9594	-5926	-2282	1103	7983
	7 - 30	-920	-268	-86	89	581	-2384	-755	482	1687	2221	-12368	-5135	-2314	901	8194
Jul	1 - 31	-1023	-196	-85	44	518	-2634	-908	307	1506	2058	-14346	-6074	-4133	-1656	5952
Aug	1 - 31	-903	-111	-43	83	517	-2538	-980	306	1522	2069	-13660	-5696	-3993	-1767	8076
Sep	1 - 30	-784	-148	-1	174	544	-2281	-834	442	1664	2136	-12243	-6412	-3862	-1195	6117
Oct	1 - 3	-614	-49	36	196	406	-1840	-528	697	1738	2076	-8638	-6929	-3661	-1210	647
	4 - 20	-753	-182	-10	167	455	-2014	-275	836	1931	2228	-10551	-7114	-4032	-894	3408
	21 - 31	-684	-149	13	161	485	-1052	675	1393	2172	2686	-9289	-5648	-3239	-309	5909
Nov	1 - 10	-977	-218	5	228	661	-2109	-33	1051	2107	2745	-11089	-5341	-2255	1248	7491
	11 - 20	-665	-45	5	100	495	-1486	389	1174	2016	2526	-9720	-5657	-3566	-1739	5367
	21 - 28	-747	-348	15	366	744	-2068	-749	547	1780	2339	-11312	-6485	-3533	79	5563
	29 - 30	-777	-435	20	404	554	-2093	-1240	386	1638	1954	-12046	-8380	-2819	1632	3627
Dec	1 - 13	-892	-424	-17	381	656	-2479	-1170	305	1682	2299	-12866	-7109	-2439	2975	9121
	14 - 31	-1151	-447	-5	450	913	-2747	-941	582	1972	2697	-14530	-6118	-1775	2847	8542

Table A-2 cont. Distribution of flows (cfs) by study period.